RRR International
10 December 2025
14:05 – 15:25

Geosynthetic-reinforced soil structures

- Developments from walls to bridges -

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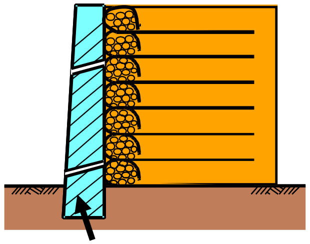
Abstract – 1/3

The developments of various types of geosynthetic-reinforced soil (GRS) structure with full-height rigid (FHR) facing, including those for High-Speed Railways, for the last about 45 years are reported. The total wall length has exceeded 221 km as of April 2025.



Full-height rigid facing

In the 1980's, GRS Retaining Wall (RW) was developed. With this structures, after the deformation of the backfill and subsoil by the construction of reinforced backfill has taken place, the FHR facing is constructed by casting-in-place fresh concrete directly on the geogrid-wrapped wall face.

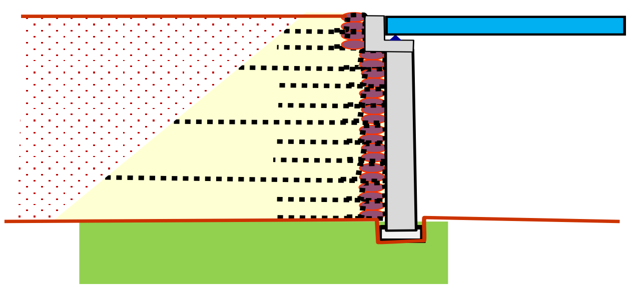
15 years after the competition, 28th Oct., 2006

Abstract – 2/3

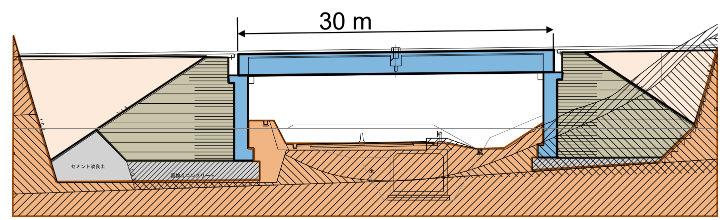
In the early 1990's, GRS Bridge Abutment was developed. With these structures, the FHR facing supports each end of a simple girder via a bearing. In total about 200 have been constructed.

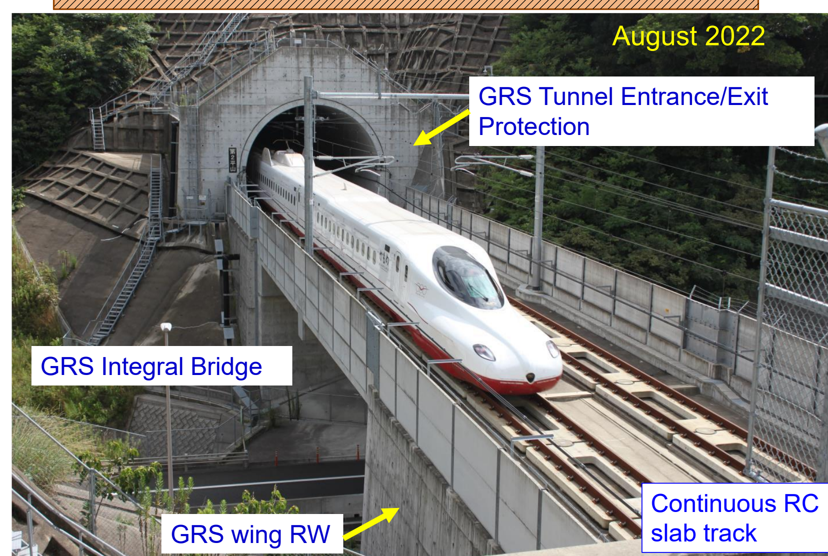
In the early 2000's, GRS Integral Bridge was developed. Both ends of a continuous girder are integrated to the top ends of FHR facings of a pair of GRS RWs. 14 have been constructed.

GRS Bridge Abutment



GRS Integral Bridge





Abstract – 3/3

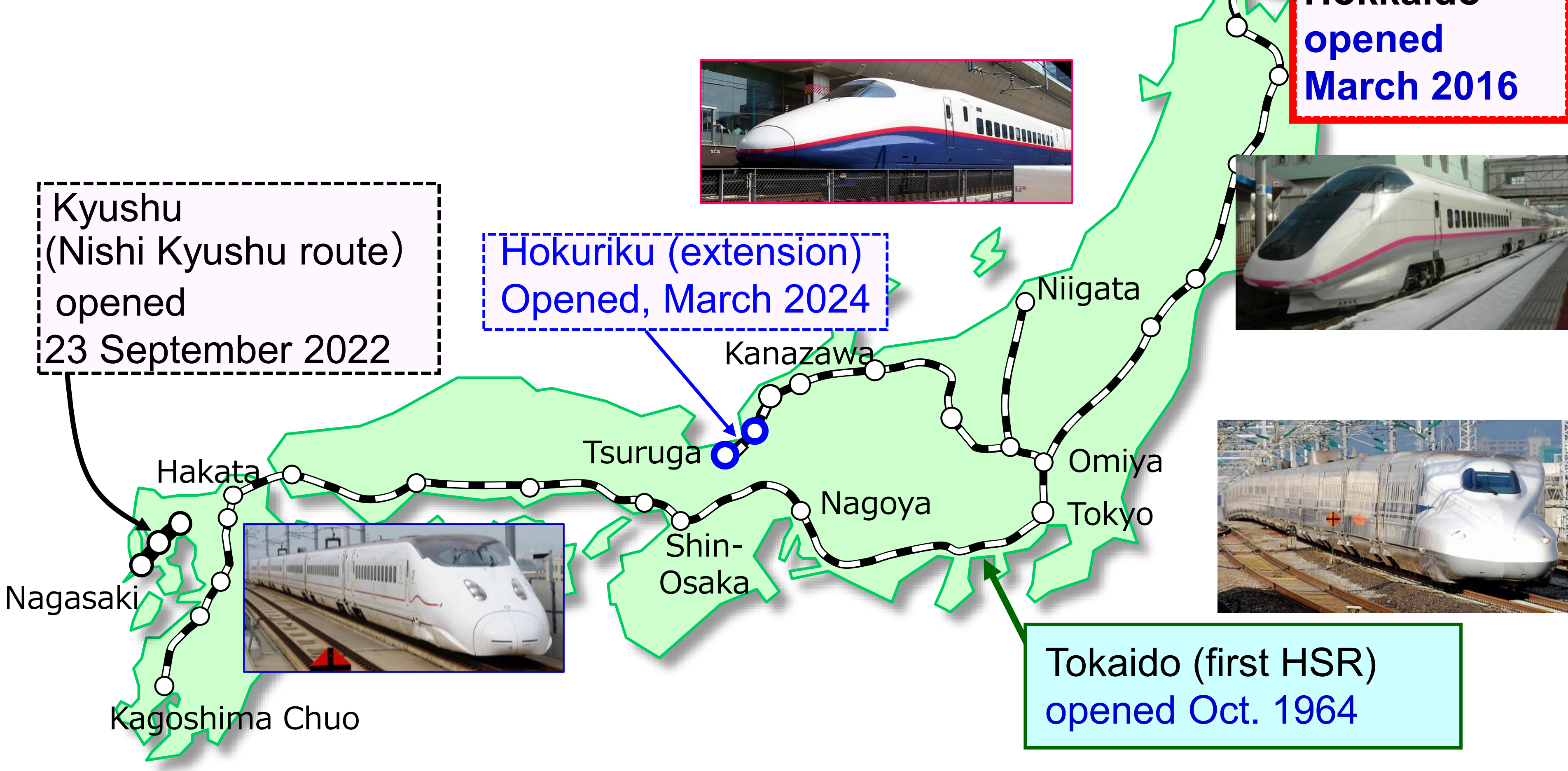
A number of conventional type embankments, RWs and bridges that collapsed by severe earthquakes, floods, ocean storm waves, tsunamis etc. were restored to RRR GRS structures with FHR facing.

The performance of all these RRR GRS structures during and after construction is satisfactory while very high cost-effectiveness has been validated.

Contents

High-Speed Railways (Shinkansen), 2025

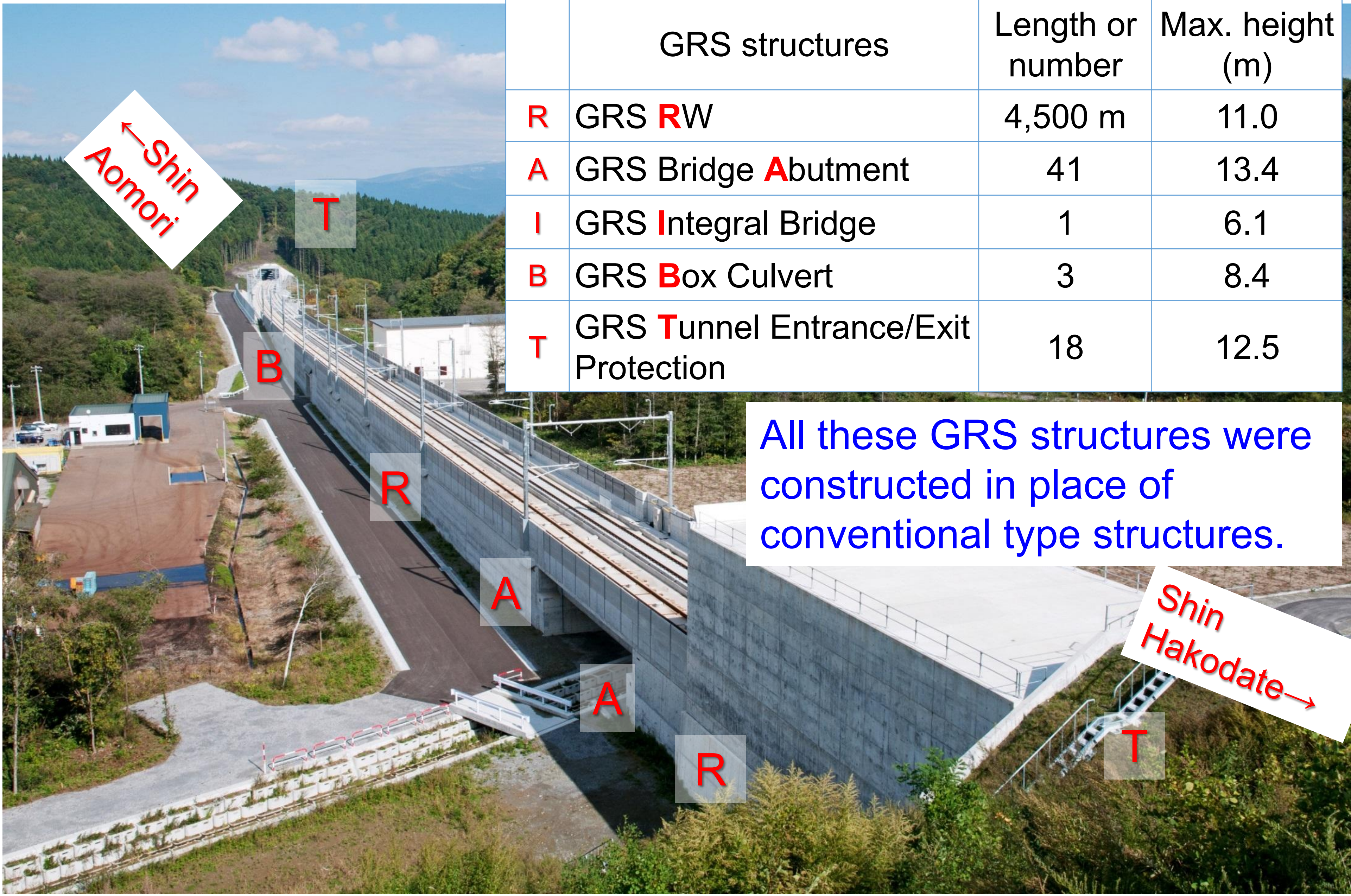
	In service	2,955.7 km (since 2000, 1120.6 km)
	Hokkaido (extension) under construction	211.5km



Mantaro site

Hokkaido Shinkansen (High Speed Railway)

	GRS structures	Length or number	Max. height (m)
R	GRS **R**W	4,500 m	11.0
A	GRS Bridge **A**butment	41	13.4
I	GRS **I**ntegral Bridge	1	6.1
B	GRS **B**ox Culvert	3	8.4
T	GRS **T**unnel Entrance/Exit Protection	18	12.5

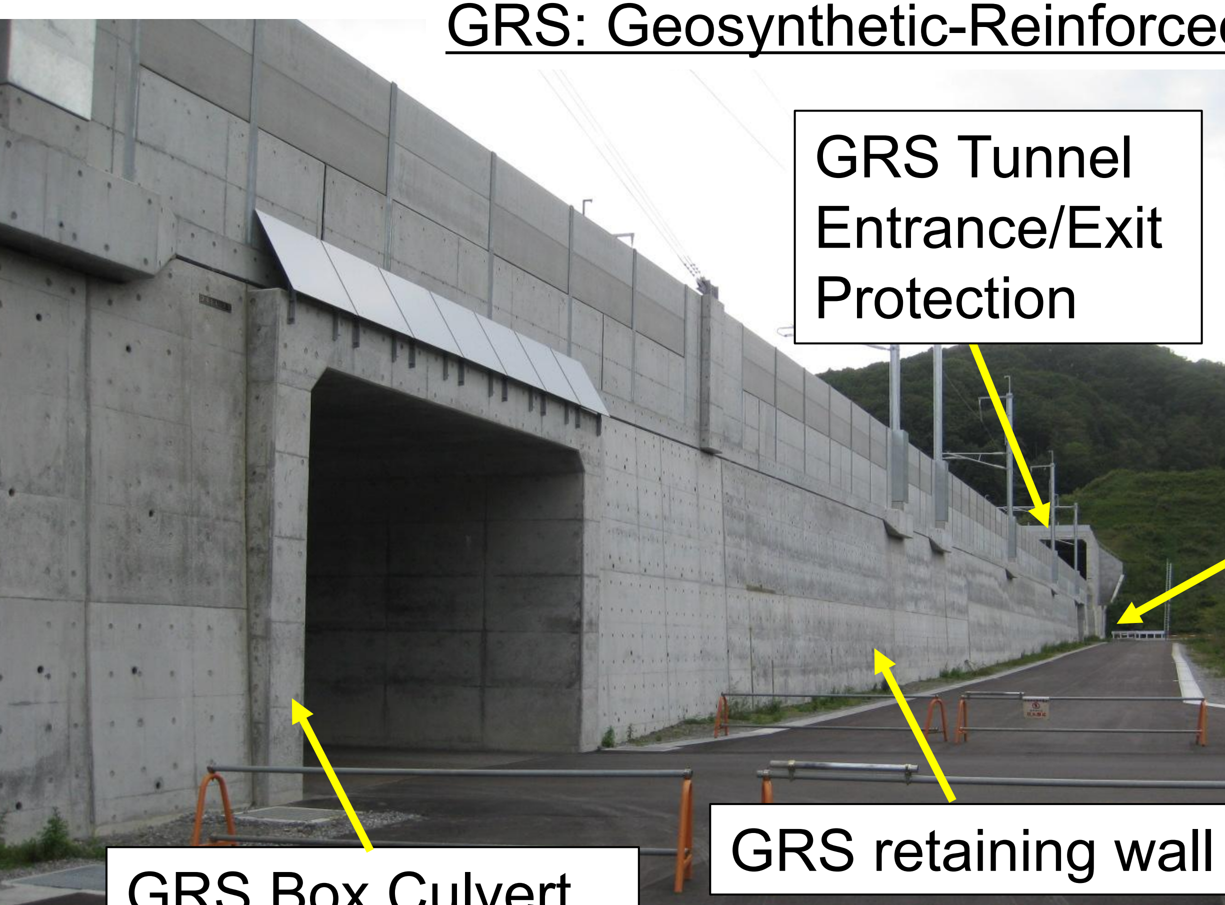


All these GRS structures were constructed in place of conventional type structures.

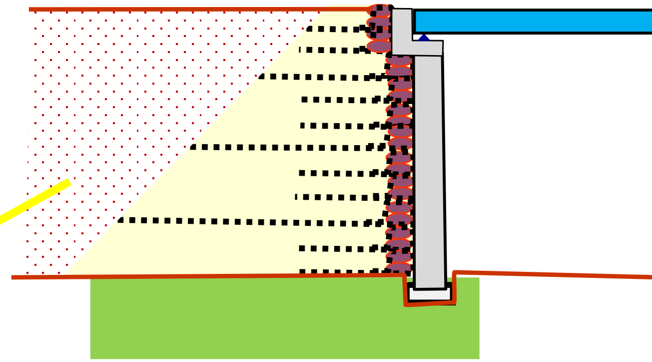
Yonezawa et al. (2014): JRTT

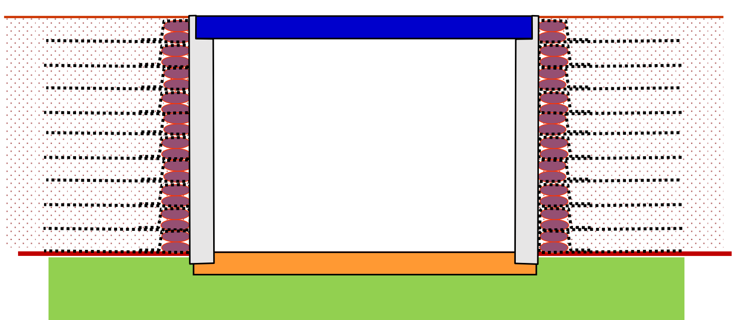
Mantaro site, Hokkaido Shinkansen

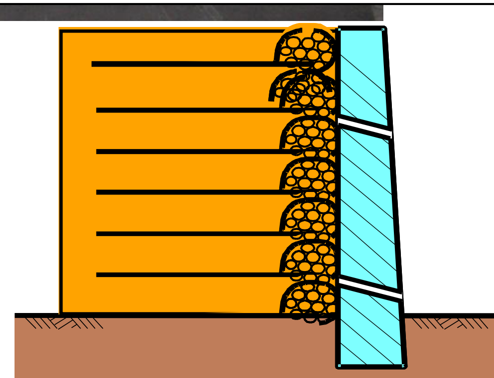
GRS: Geosynthetic-Reinforced Soil



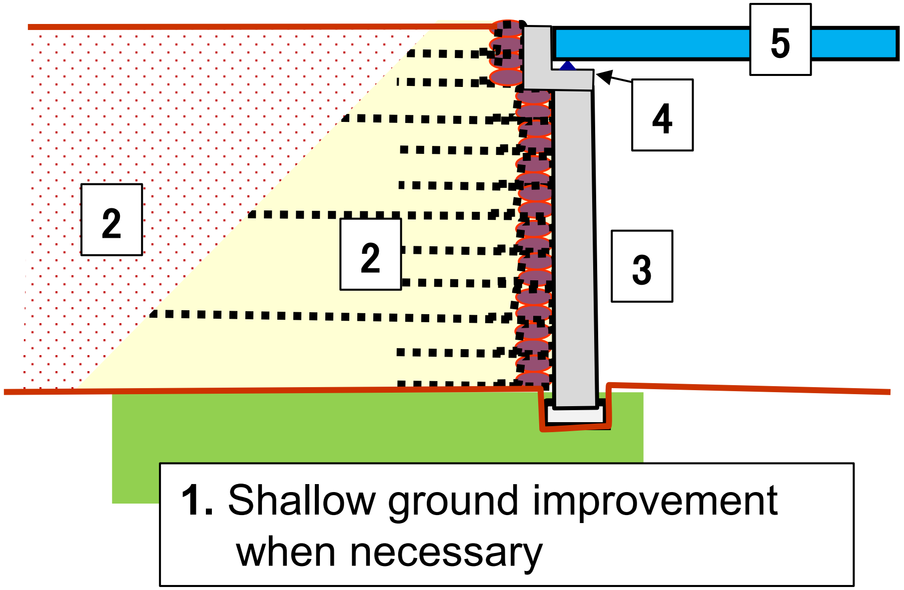
GRS Bridge Abutment







GRS Bridge Abutment



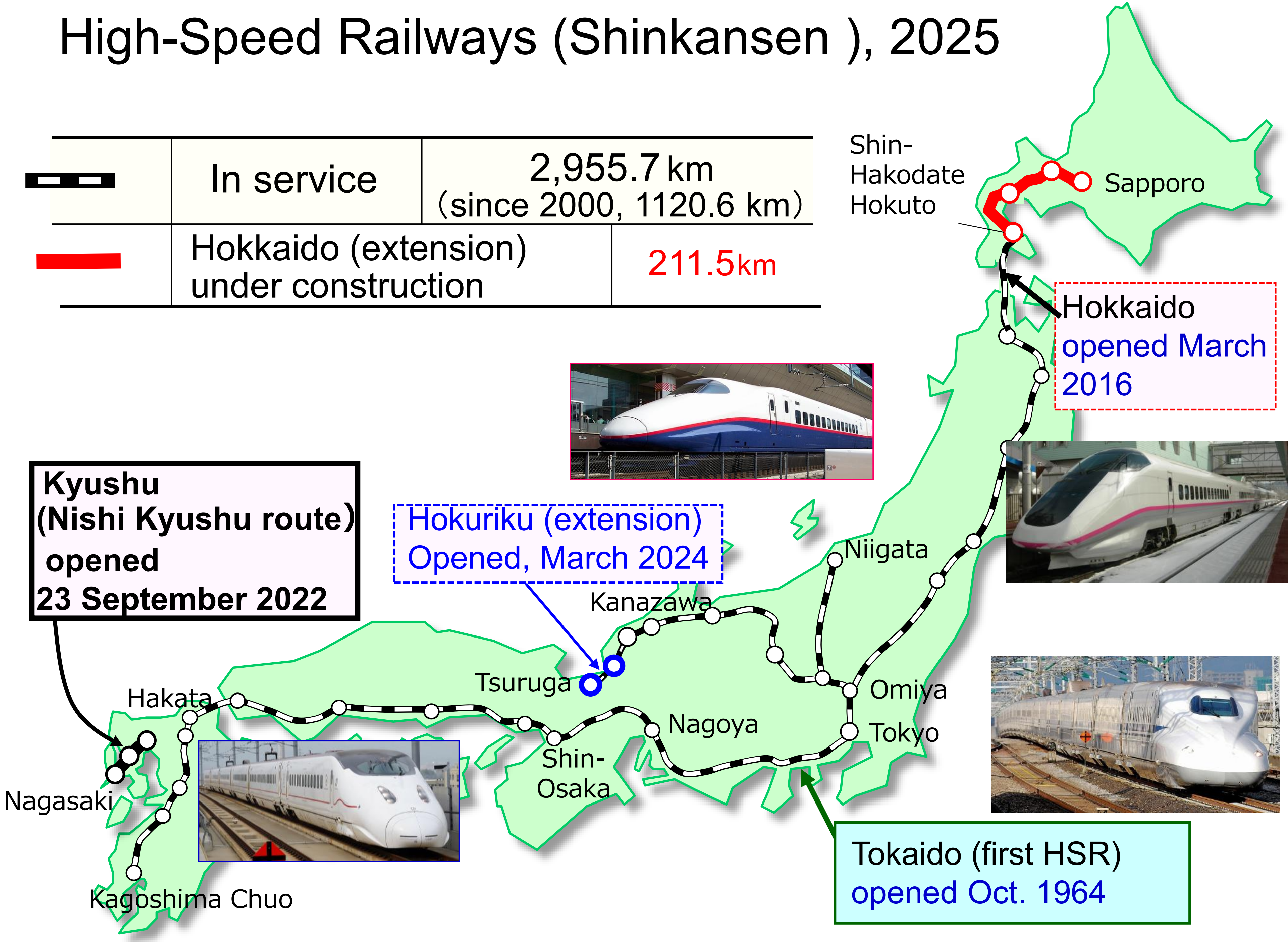
13.4 m-high, Mantaro site

Under construction
Oct. 2011

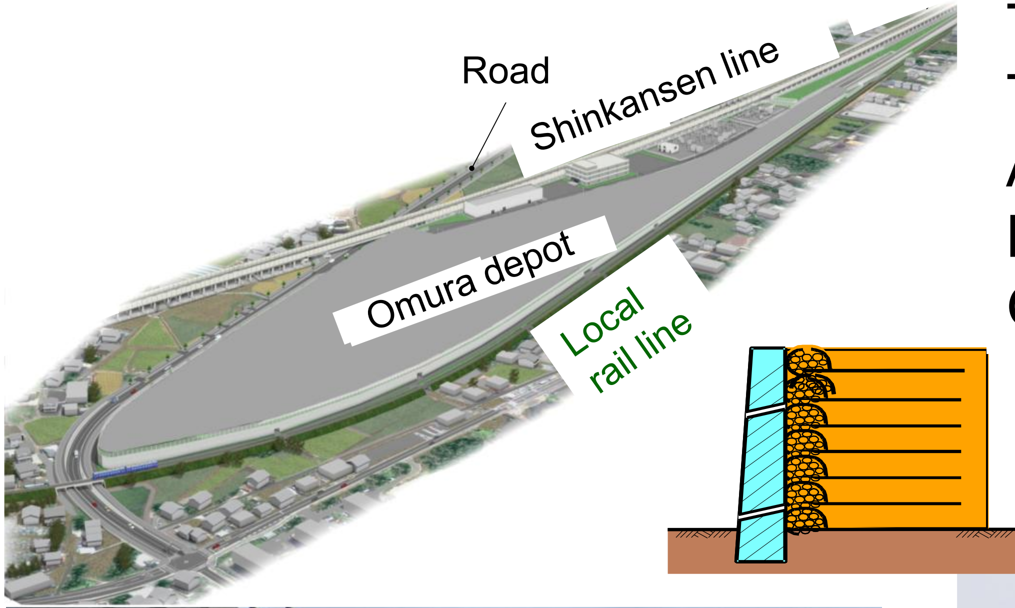
Completed
Aug. 2012

High-Speed Railways (Shinkansen), 2025

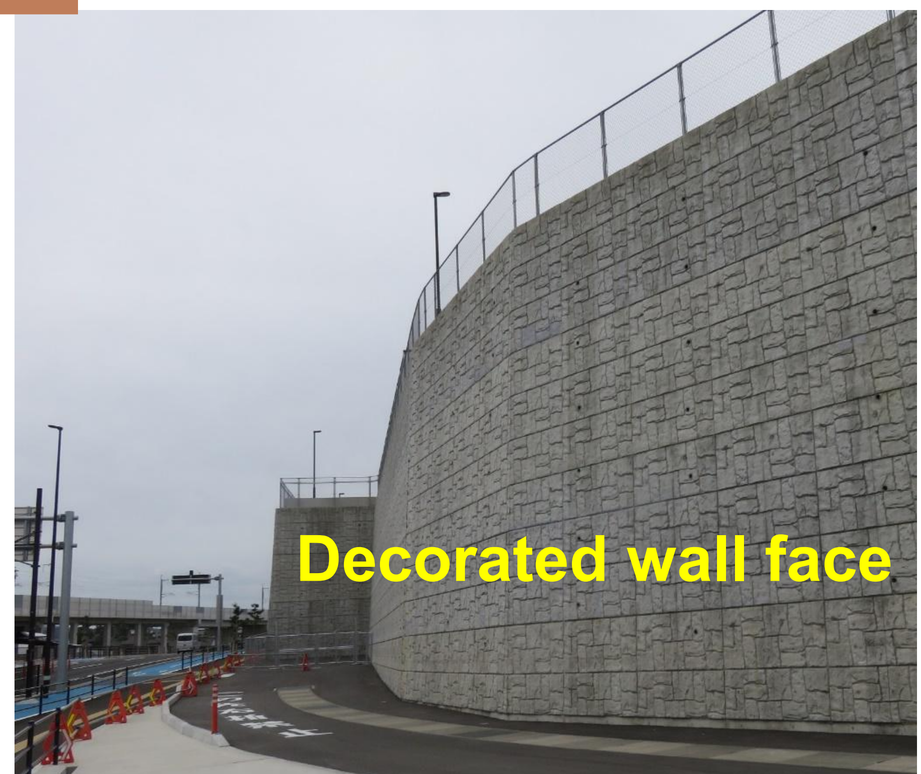
(black-white dashed line)	In service	2,955.7 km (since 2000, 1120.6 km)
(red line)	Hokkaido (extension) under construction	211.5km



GRS RWs at Omura Depot

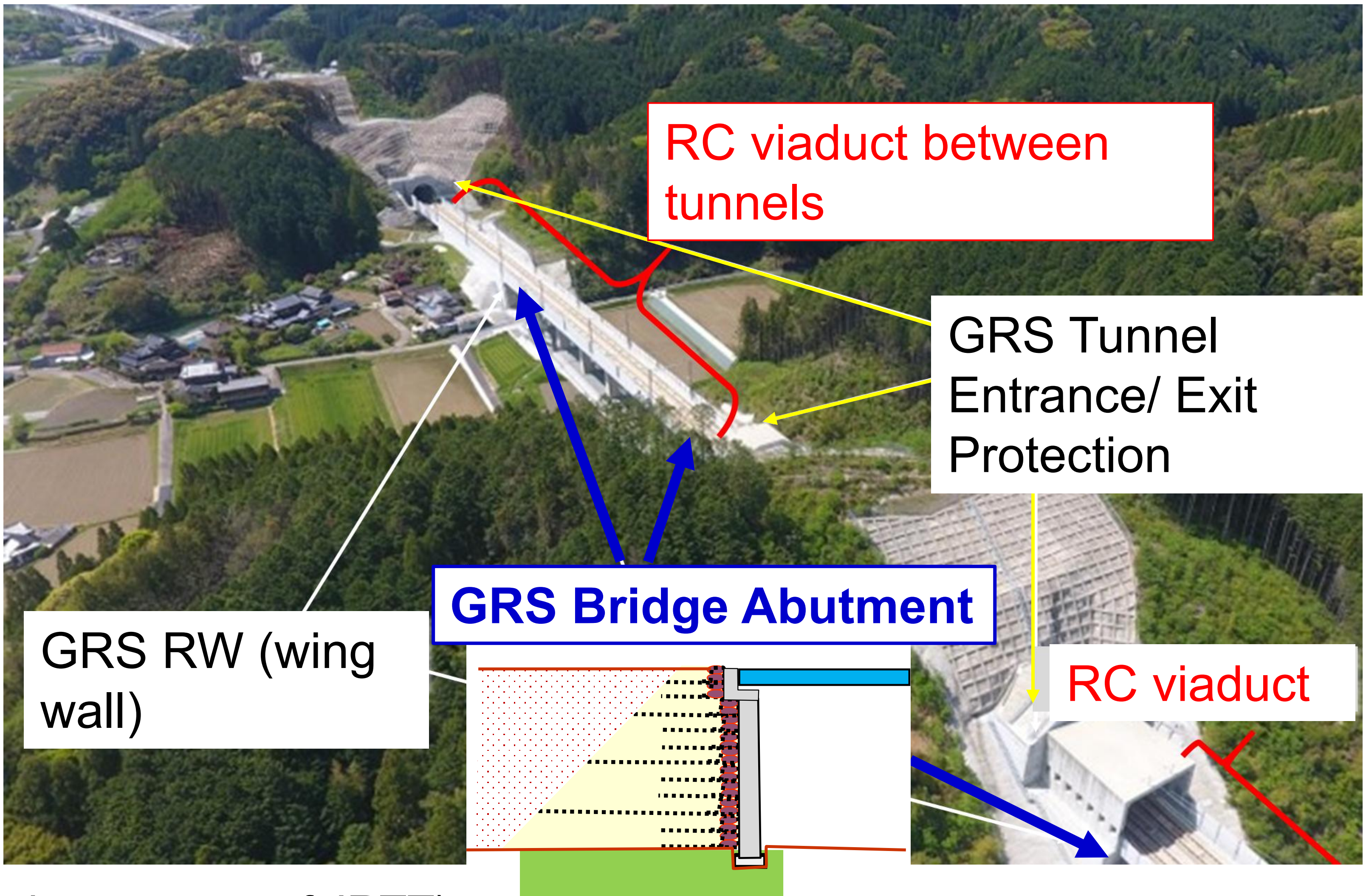


Total wall length: 1.7 km
Total wall area: 17,200 m^2
Average wall height: 9 m
Maximum wall height: 12.4 m
GRD RW area: 240,000 m^2



In this route of High-Speed Railway, in total 88 bridge abutments were constructed at the tunnel exits.

Among 88, 78 (i.e., 89 %) are RRR GRS Bridge Abutments !



(By the courtesy of JRTT)

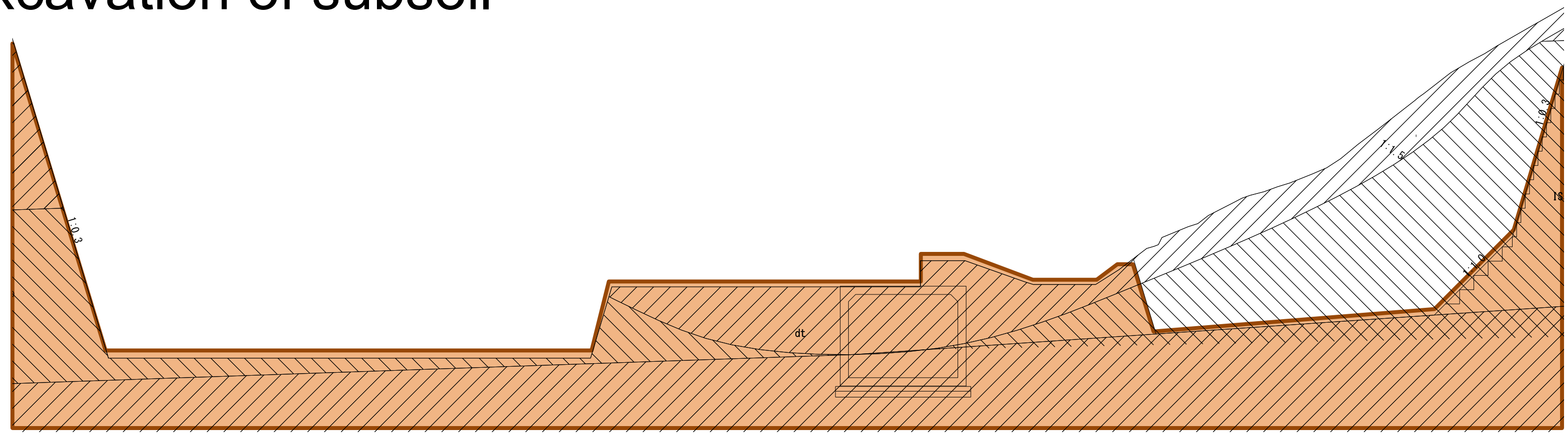
Kyushu Shinkansen, Nishi-Nihon Route, San-nose Tunnel

27 Oct. 2022

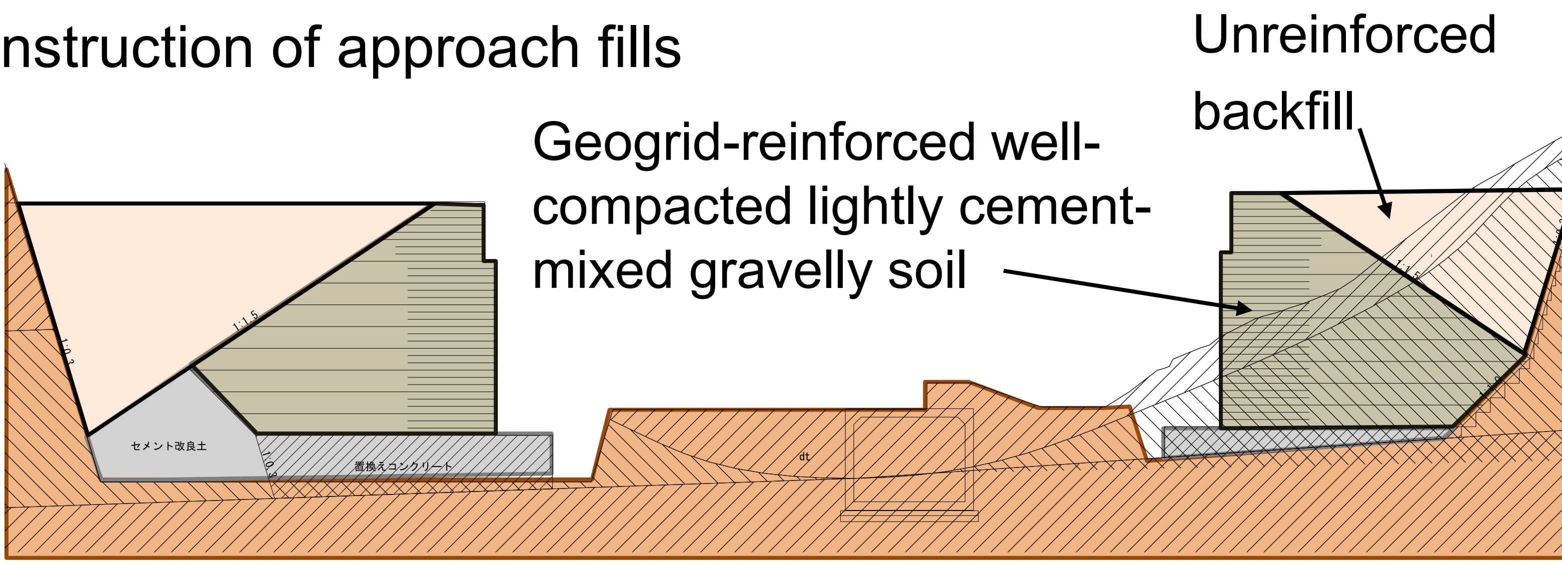

GRS Bridge
Abutment

GRS Integral Bridge at Genshu, construction procedure

1. Excavation of subsoil



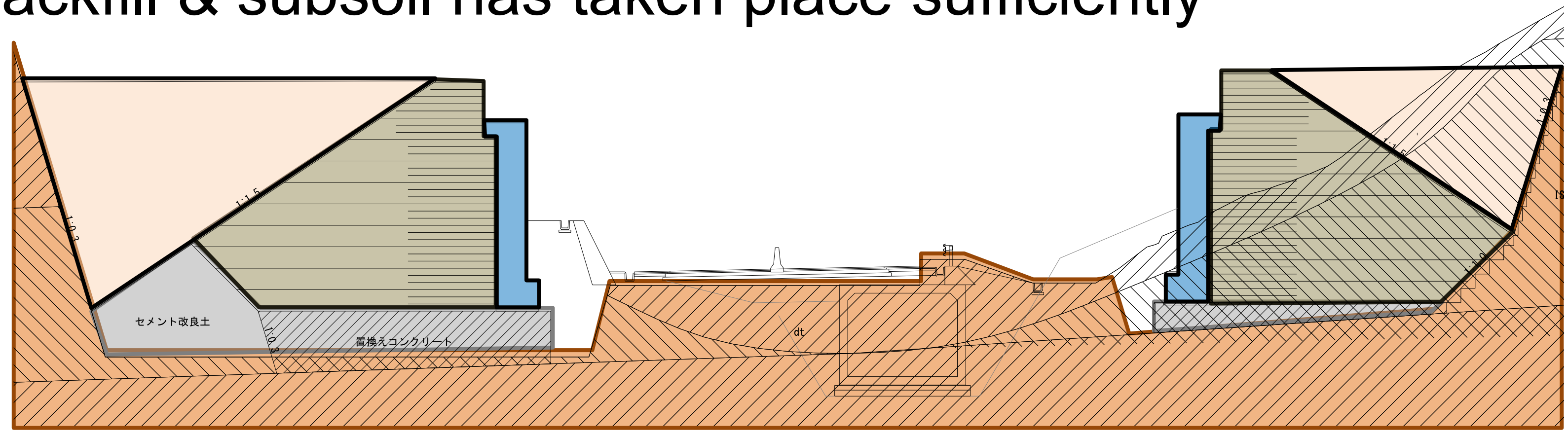
2. Construction of approach fills



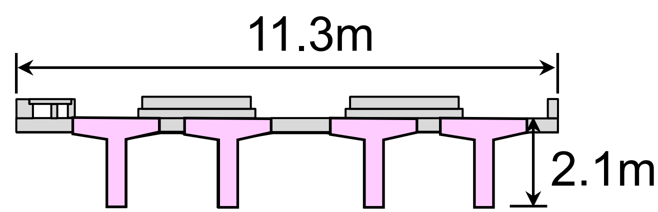
Soga et al. (2018) & JRTT

GRS Integral Bridge at Genshu

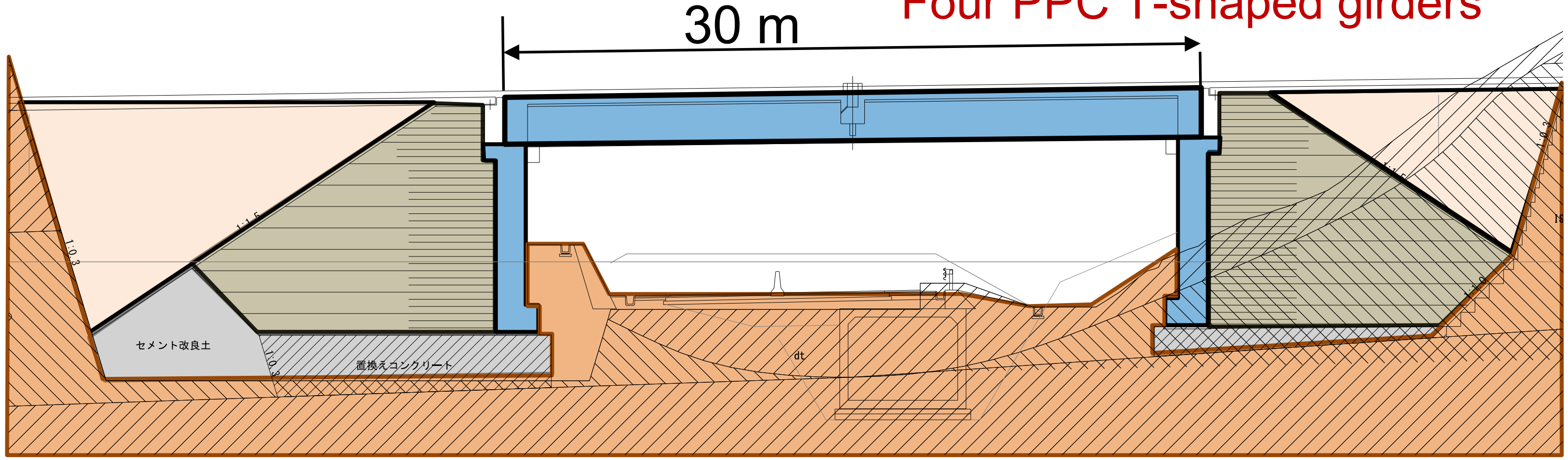
3. Construction of FHR RC facings after the deformation of the backfill & subsoil has taken place sufficiently



4. Arrangement of PC girders



Four PPC T-shaped girders

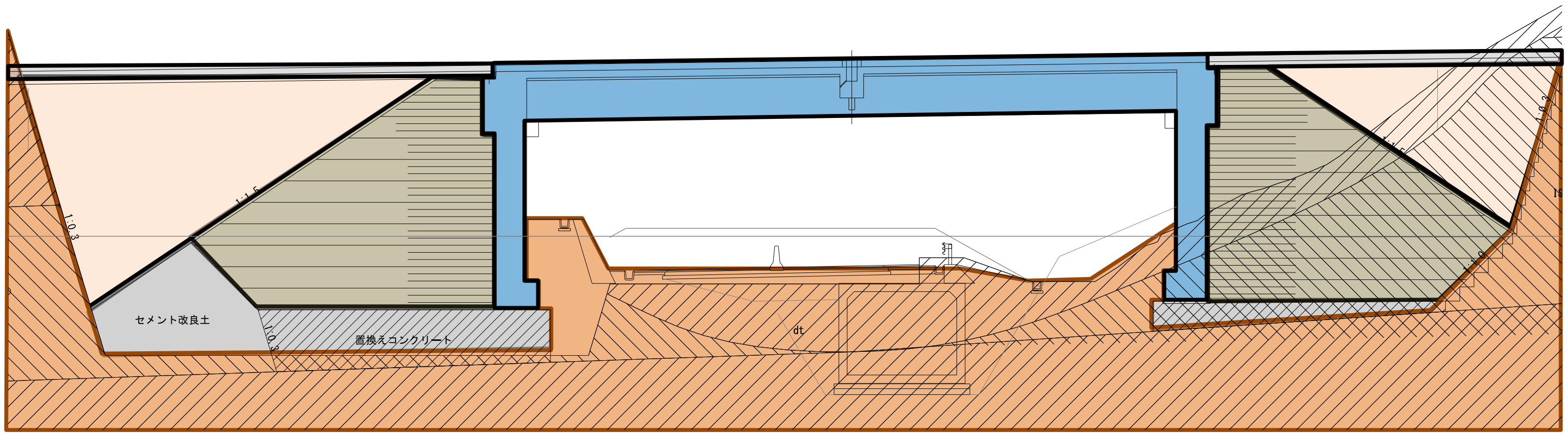


Arrangement of a 30 m-long PC girder

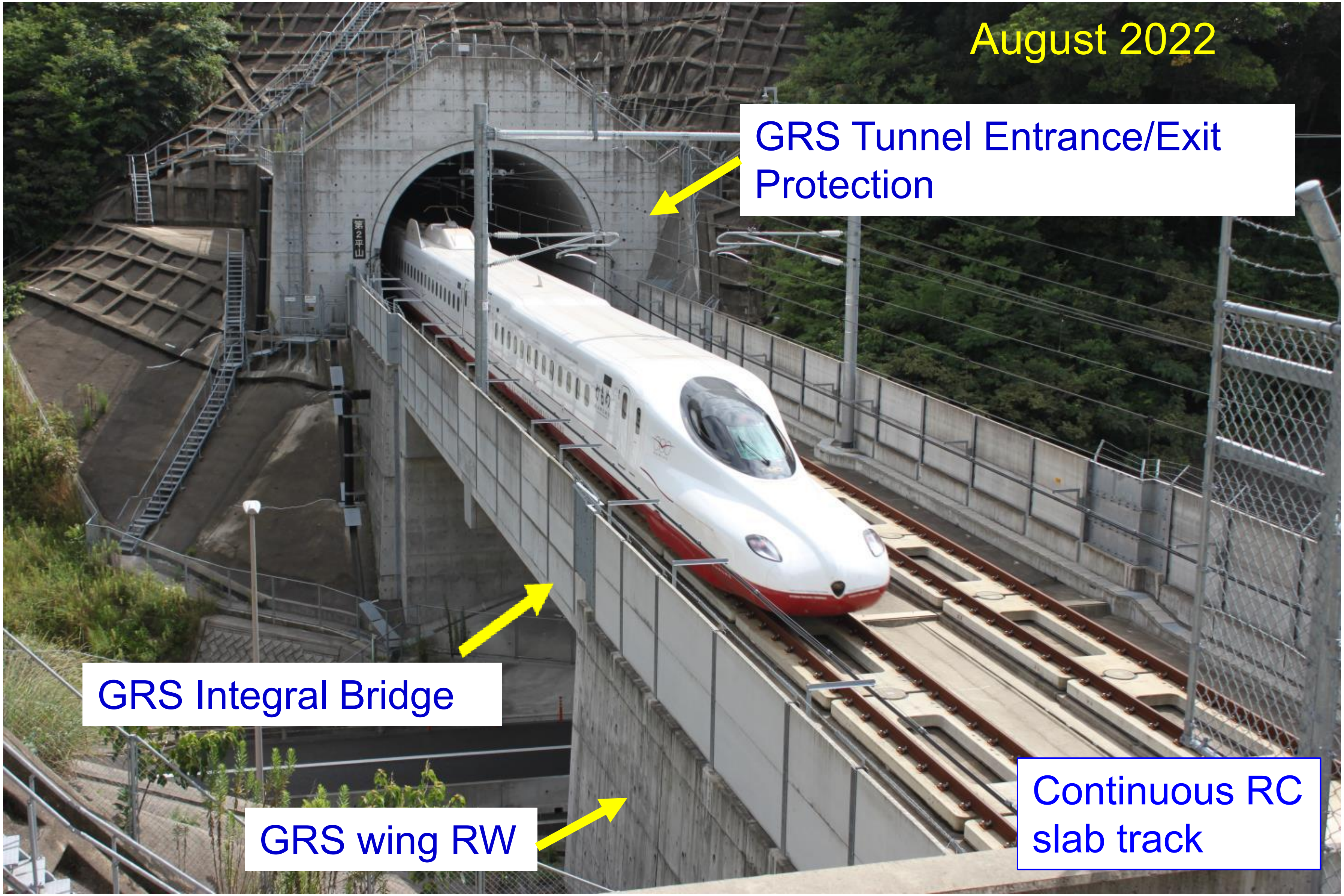
GRS Integral Bridge at Genshu, Kyushu

GRS Integral Bridge at Genshu

5. Structural integration of both ends of the girders to the FHR facings, then construction of slab & others to complete the bridge

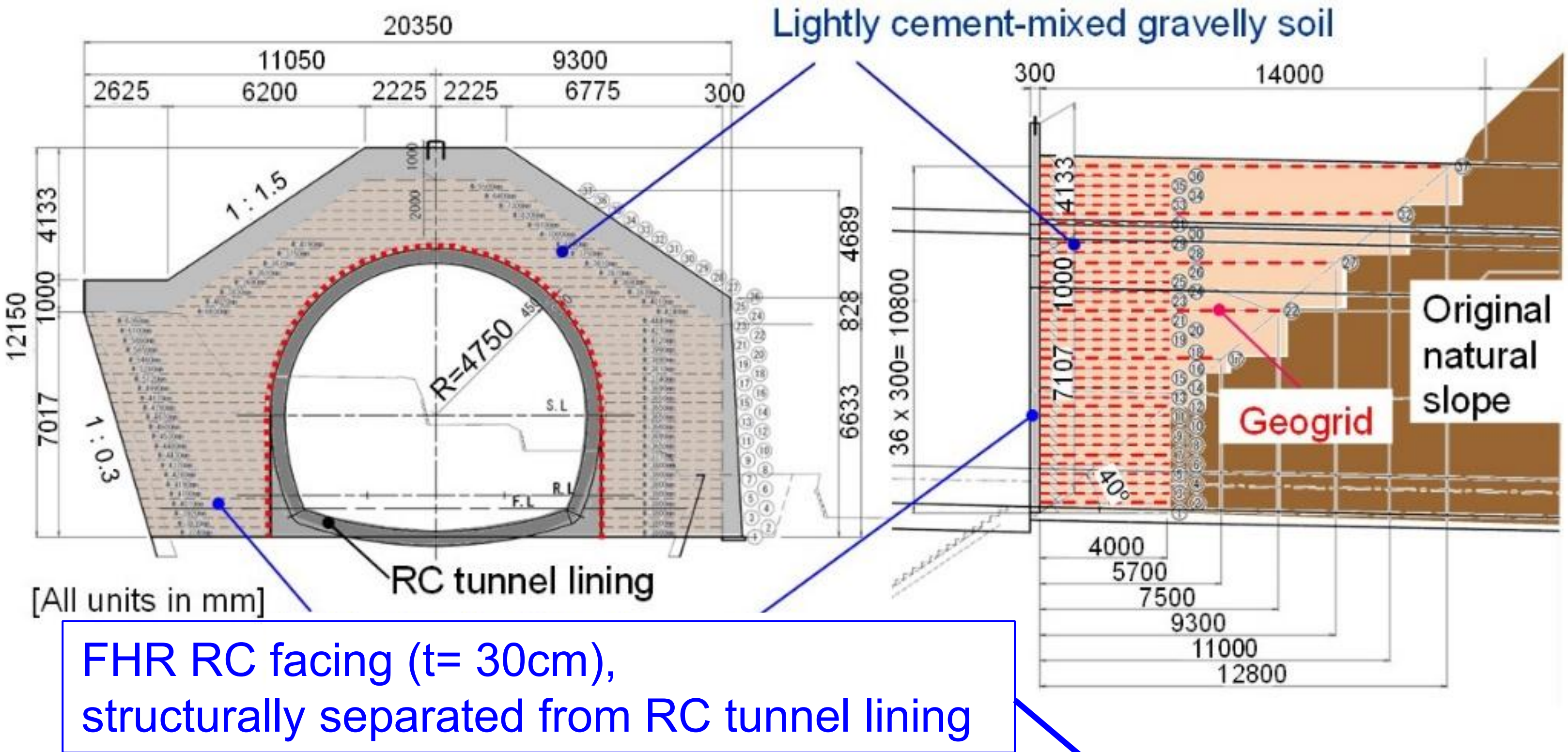


Completed GRS Integral Bridge at Genshu



By the courtesy of JRTT

GRS Tunnel Entrance/Exit Protection



Arrangement of geogrid layer

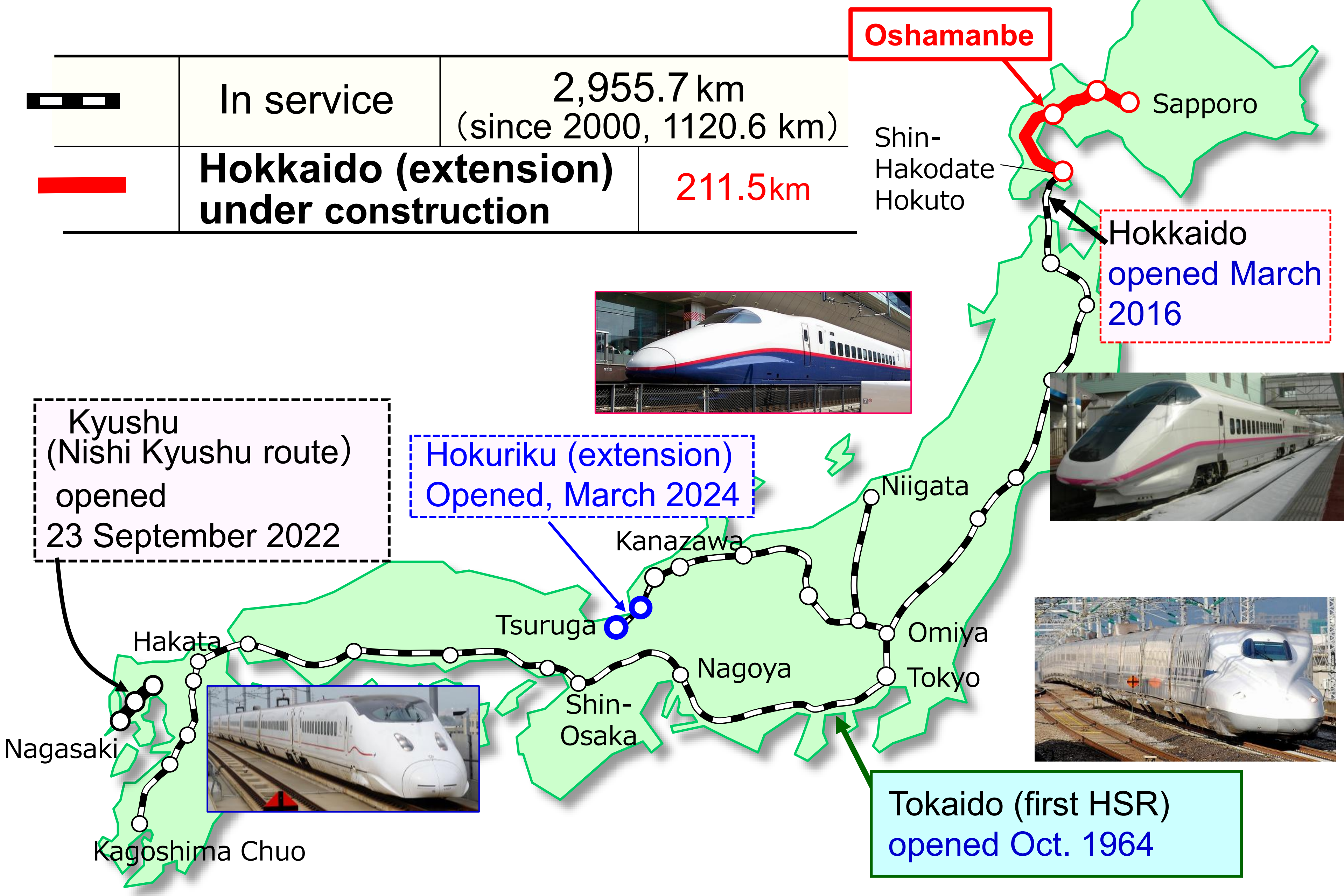
Construction of GRS walls on both sides of tunnel

Construction of FHR RC facing

Soga et al. (2018) & JRTT

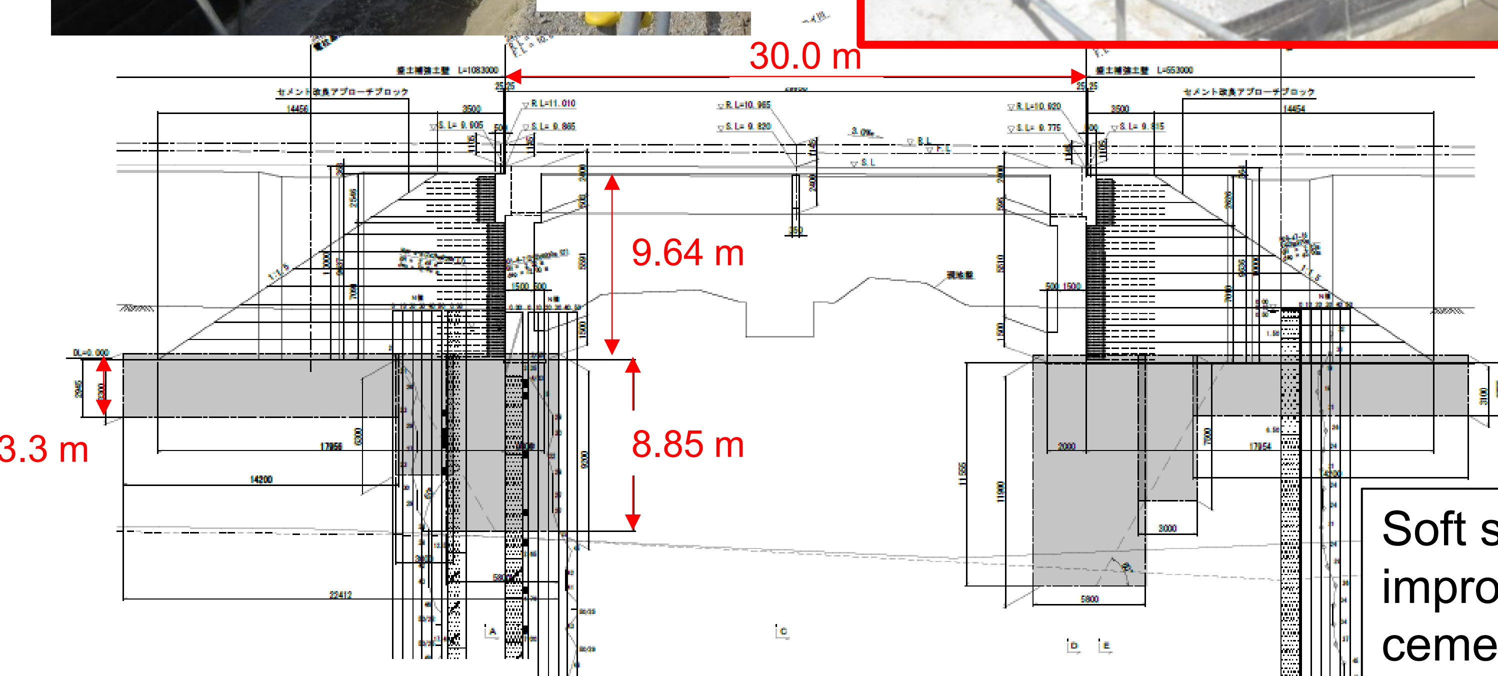
High-Speed Railways (Shinkansen), 2025

(black-and-white line)	In service	2,955.7 km (since 2000, 1120.6 km)
(red line)	**Hokkaido (extension) under construction**	211.5km



GRS Integral Bridge under construction

Oshamanbe site,
Hokkaido Shinkansen



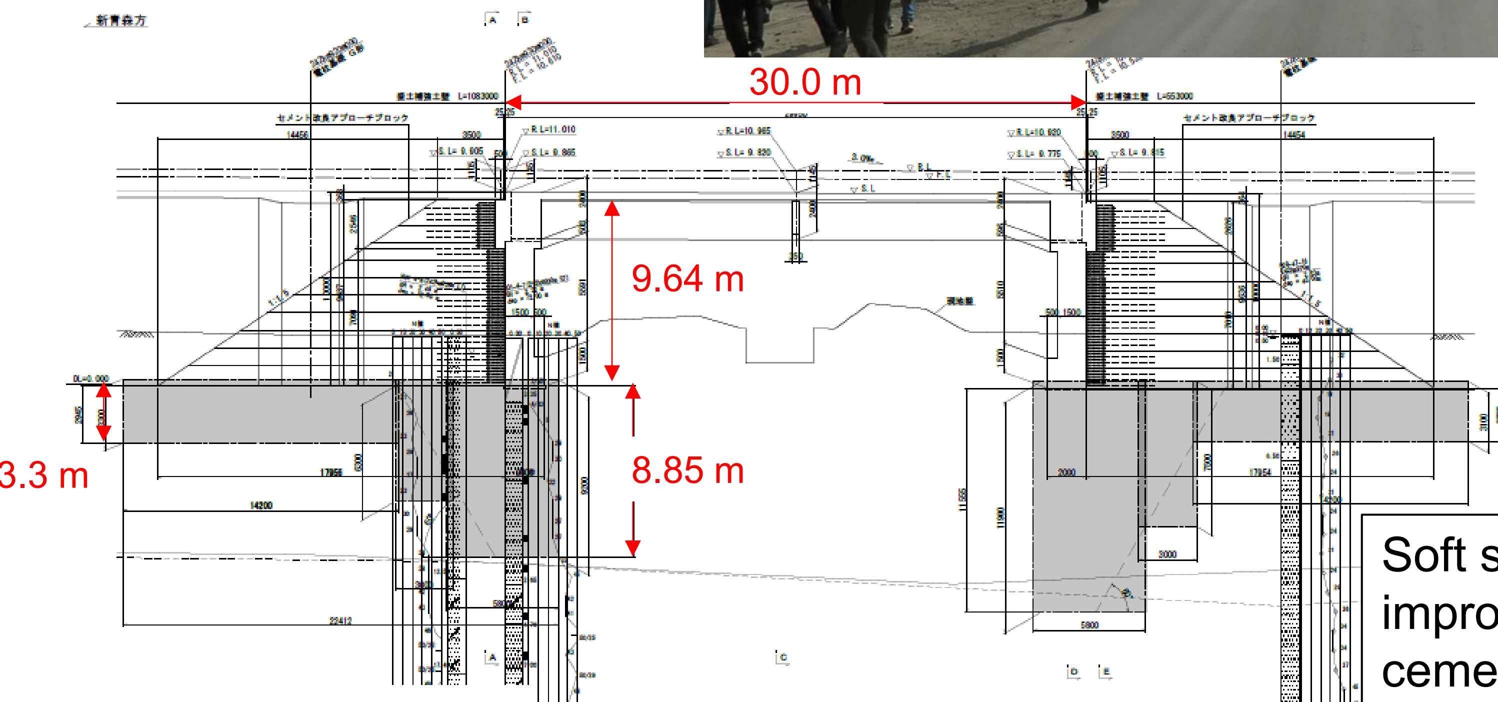
Soft subsoil layer, improved by shallow cement-mixing in–place

By the courtesy of JRTT

GRS Integral Bridge under construction

Oshamanbe site,
Hokkaido Shinkansen

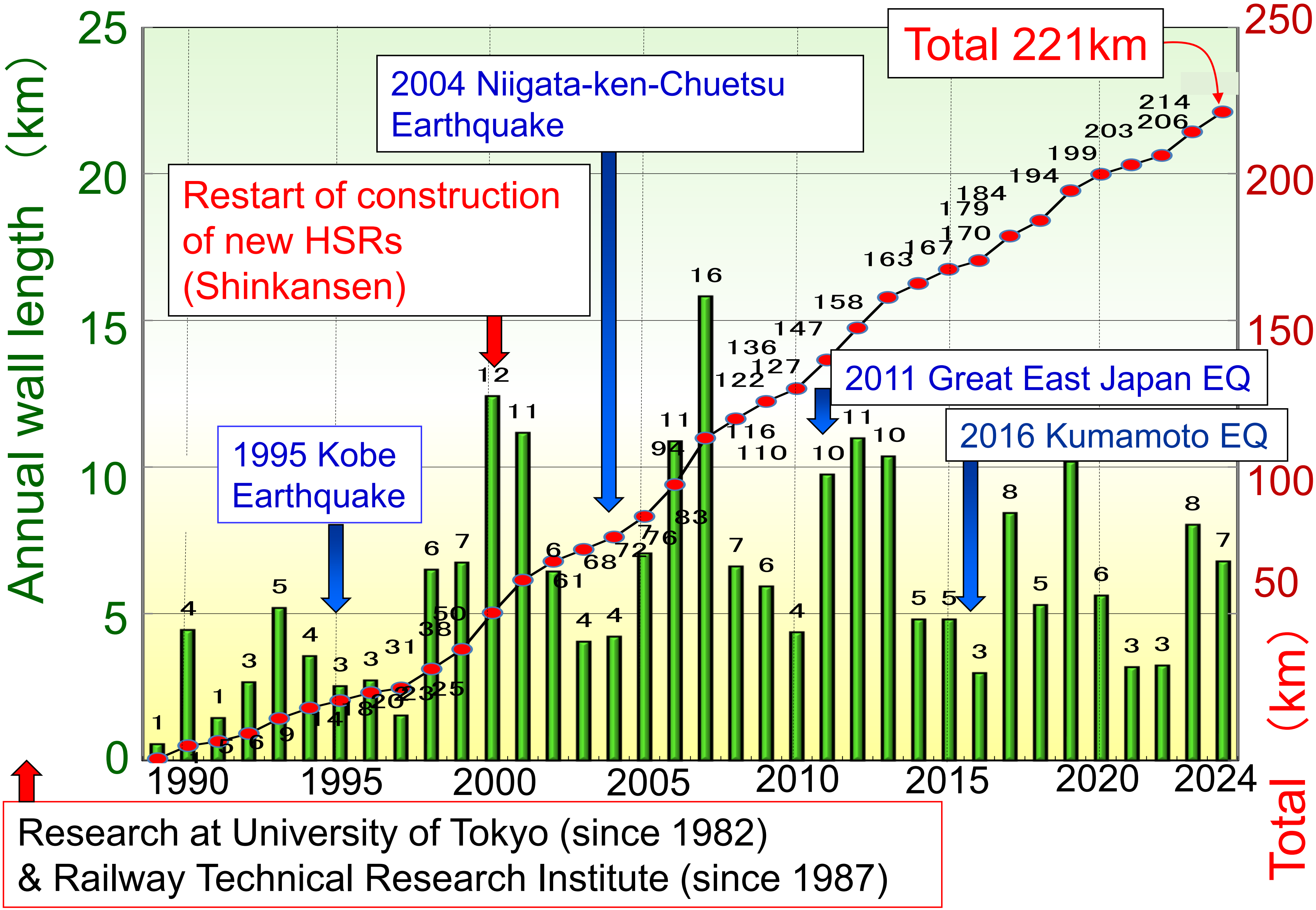
21 May 2025
Tatsuoka



Soft subsoil layer, improved by shallow cement-mixing in–place

By the courtesy of JRTT

History of RRR-GRS structures (as of April 2025)



Locations of completed RRR-GRS RWs, Bridge Abutments, Integral Bridges etc. (April 2025)

Total completed wall length: **221** km

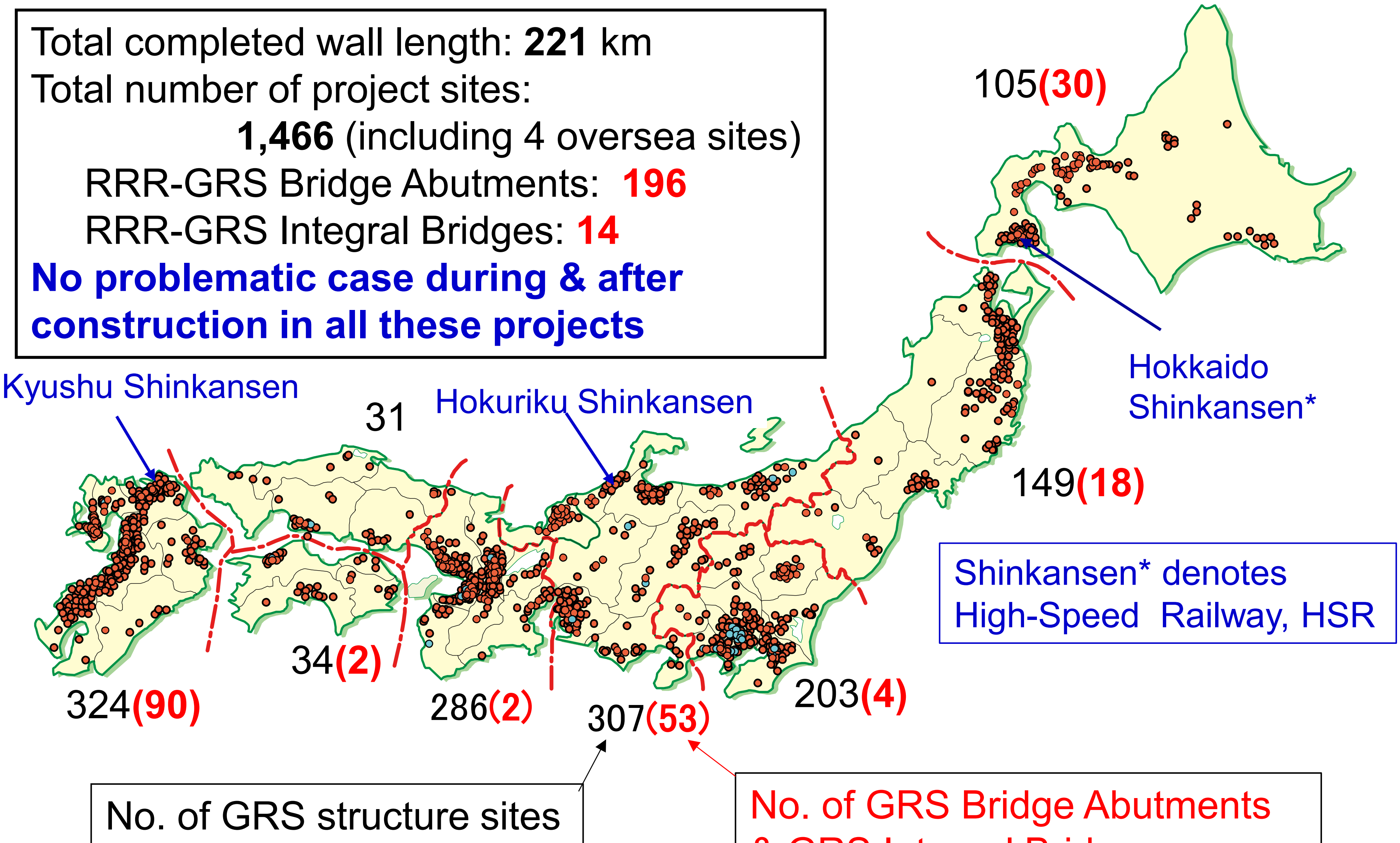
Total number of project sites:

1,466 (including 4 oversea sites)

RRR-GRS Bridge Abutments: **196**

RRR-GRS Integral Bridges: **14**

No problematic case during & after construction in all these projects



Summary:

A number of Geosynthetic-Reinforced Soil (GRS) structures with FHR facing have been constructed in place of conventional type RWs, bridge abutments & simple girder bridges. In Japan, these GRS structures have become the standard railway soil structures. GRS structures have been also constructed for roads. Besides, they were constructed at several oversea sites in Vietnam, Indonesia and Philippines, and soon in India.

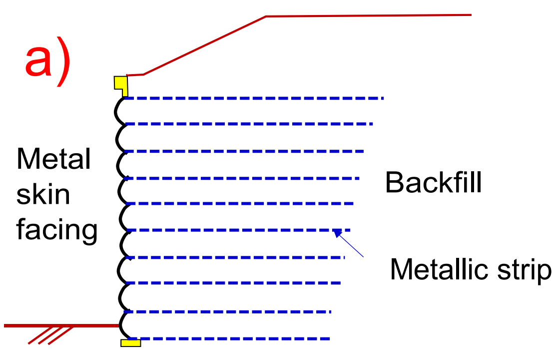
This success can be attributed to the fact that, compared with conventional type soil structures, these RRR-GRS structures exhibit:

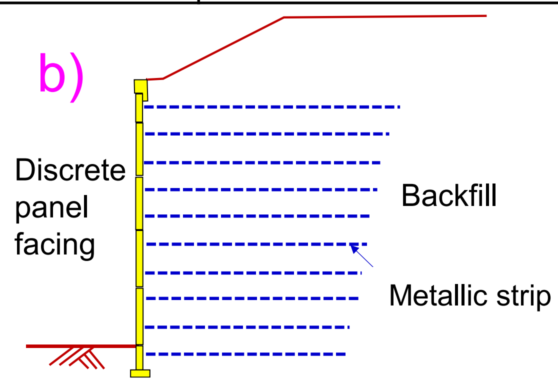
1. higher performance against
   - long-term static & traffic loads; and
   - severe earthquakes, heavy/prolonged rainfalls, strong floods, ocean stormwaves & tsunamis; and
2. lower cost for construction & long-term maintenance.

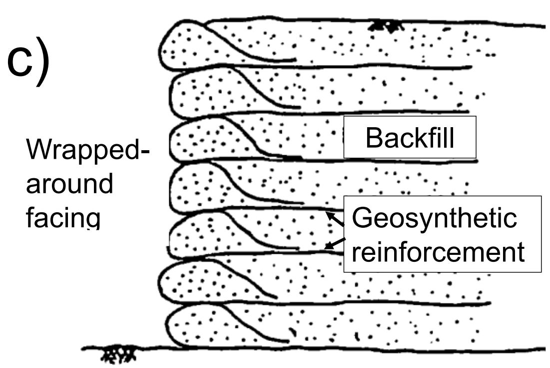
Contents

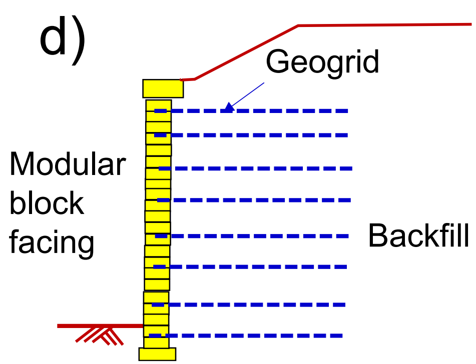
Various types of mechanically stabilized earth (MSE) RW:
flexible vs. stiff facing and inextensible vs. extensible reinforcement

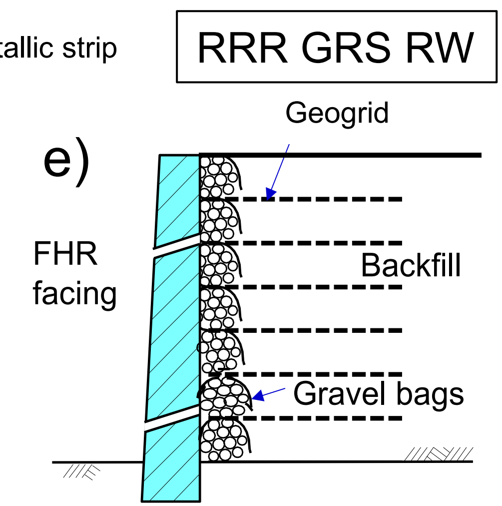
Facing / Reinforcement	Flexible, not developing high earth pressure on the facing	Stiff, developing high earth pressure on the facing
Inextensible: e.g., metallic strip	a) Metallic skin facing	b) Discrete concrete panel facing
Extensible: typically polymeric planar geogrid	c) Wrapped-around facing	Typically, **d**) Modular block facing; & **e**) Full-height rigid (FHR) facing

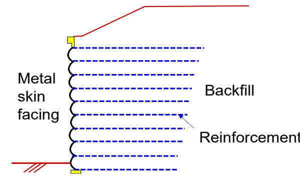
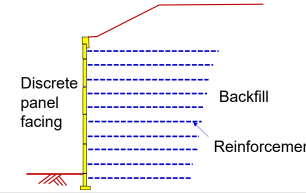
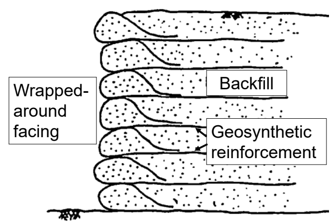
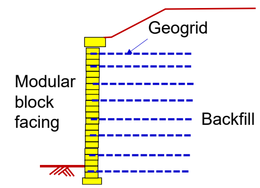
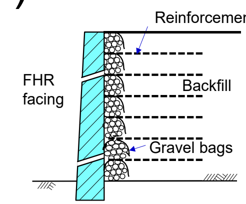










<table>
<tr><td>Facing
Reinforcement</td><td>Flexible, not developing high earth pressure on the facing</td><td>Stiff, developing high earth pressure on the facing</td></tr>
<tr><td>Inextensible:
e.g., metallic strip</td><td>a) Metallic skin facing
</td><td>e.g., b) Discrete concrete panel facing
</td></tr>
<tr><td>Extensible: typically polymeric & planar (e.g., geogrid)</td><td>c) Wrapped-around facing
</td><td>e.g., d) Modular block facing, & e) FHR facing

</td></tr>
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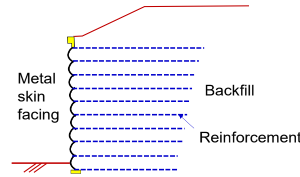
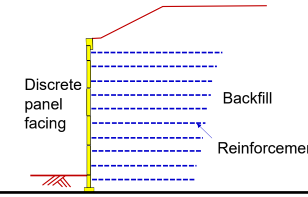
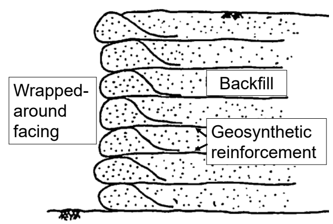
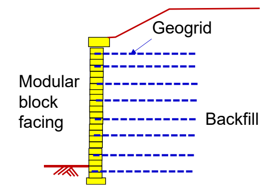
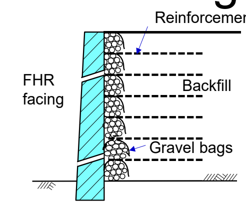
Previously, many considered that:

- for small wall deformation and high wall stability, it is necessary to use **inextensible reinforcement, such as metallic strips (i.e., a & b).**

However, this notion is not realistic !

That is, although geogrid is relatively extensible,

- geogrid reinforcement is planar with a high pull-out strength;
- geogrid is stiff enough to effectively reinforce the backfill when arranged at a small vertical spacing (e.g., 30 cm); and
- geogrid is free from corrosion.

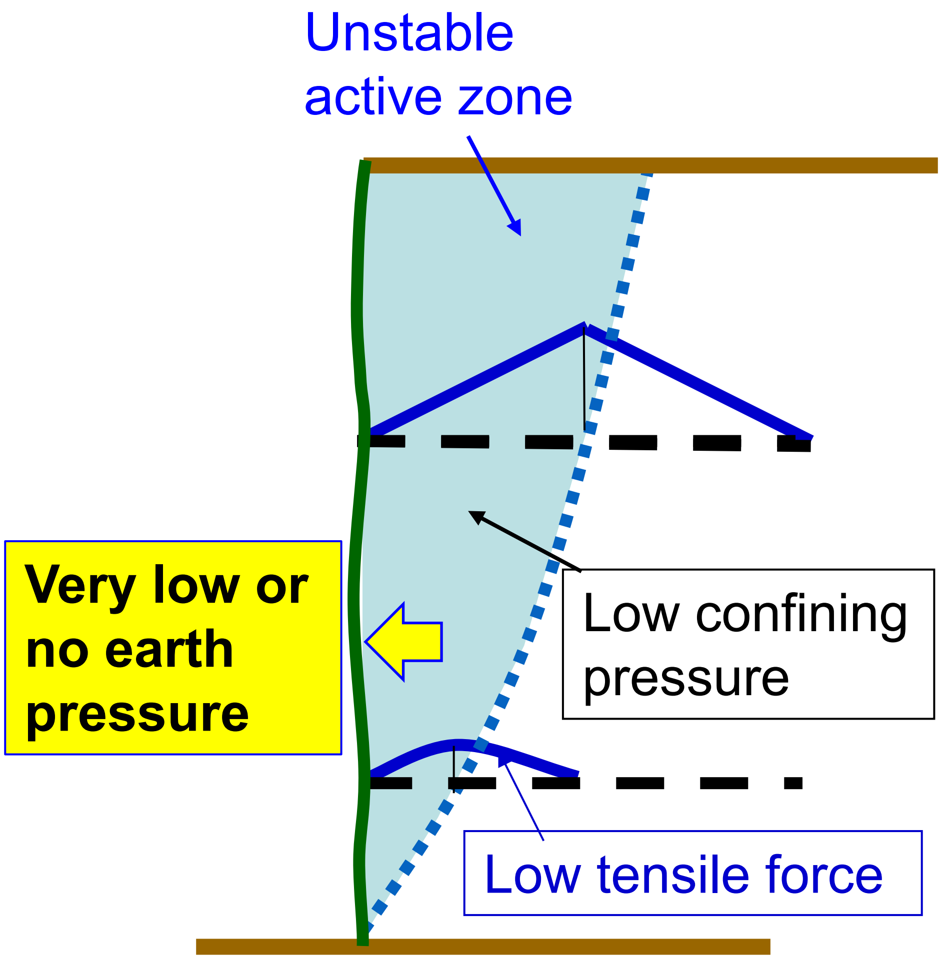
Facing / Reinforcement	Flexible, not developing high earth pressure on the facing	Stiff, developing high earth pressure on the facing
Inextensible: e.g., metallic strip	a) Metallic skin facing 	b) Discrete concrete panel facing 
Extensible: typically polymeric planar geogrid	c) Wrapped-around facing 	Typically, **d**) Modular block facing, & **e**) FHR facing  

Previously, many considered that:

- facing is necessary only to prevent the spilling out of backfill; and
- the earth pressure on the facing should be kept **low** for small wall deformation and high wall stability, so, **flexible facing** (e.g., a or **c**) is sufficient.

However, we often observed that:
when using flexible facing (e.g., a or **c**), the earth pressure is low, whereas **the wall deformation is large, sometimes too large,** indicating the paramount importance of using stiff facing to develop high earth pressure.

When the facing is flexible ....

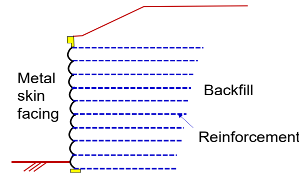
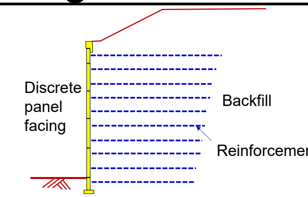
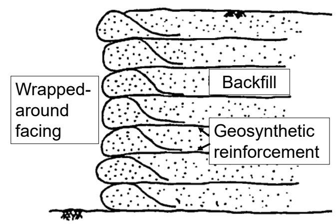
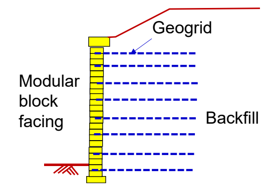
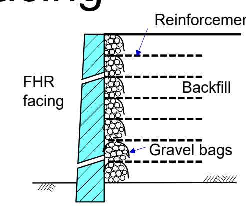


Very low earth pressure on the facing, results into:

→ low tensile forces in the reinforcement, in particular at low levels in the wall; and

→ in the active zone, low confining pressure, therefore, low strength & stiffness of the backfill,

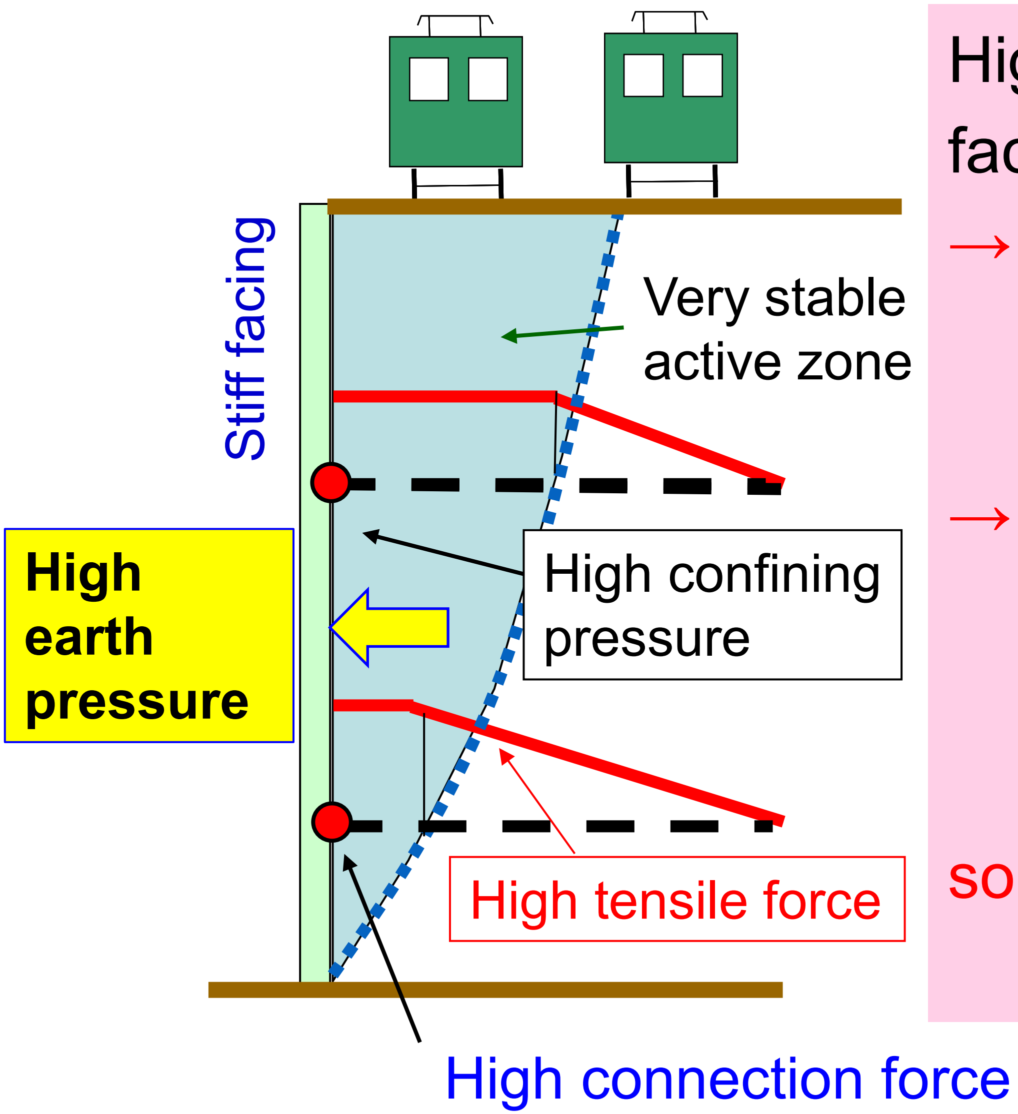
so, large wall deformation & low stability of the wall

Reinforcement \ Facing	Flexible, not developing high earth pressure on the facing	Stiff, developing high earth pressure on the facing
Inextensible: e.g., metallic strip	**a**) Metallic skin facing 	**b**) Discrete concrete panel facing 
Extensible: typically polymeric planar geogrid	**c**) Wrapped-around facing 	Typically, **d**) Modular block facing, & **e**) FHR facing  

On the other hand, we consistently observe that:

when the facing is stiff and firmly connected to the reinforcement layers (e.g., **b**, **d** & **e**), large earth pressure develops, which results in small wall deformation and high wall stability.

When stiff facing is firmly connected to reinforcement....



High earth pressure on the facing, resulting into:

→ high tensile forces in the reinforcement (even at low levels in the wall); and

→ in the active zone, high confining pressure, therefore, high strength & stiffness of the backfill,

so, small wall deformation & high stability of the wall

<table>
<tr><th>Facing / Reinforcement</th><th>Flexible, not developing high earth pressure on the facing</th><th>Stiff, developing high earth pressure on the facing</th></tr>
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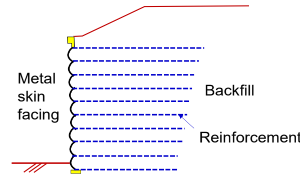
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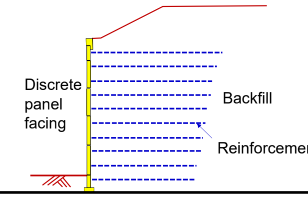
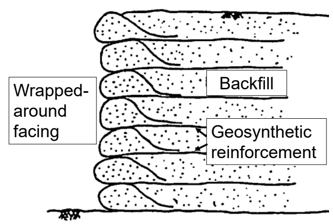
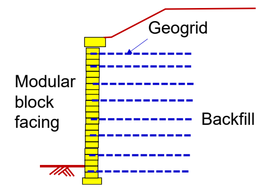
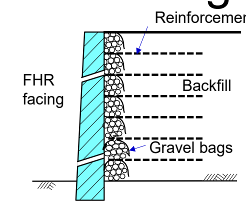

</td></tr>
<tr><td>Extensible: typically polymeric planar geogrid</td><td>c) Wrapped-around facing

</td><td>d) Modular block facing


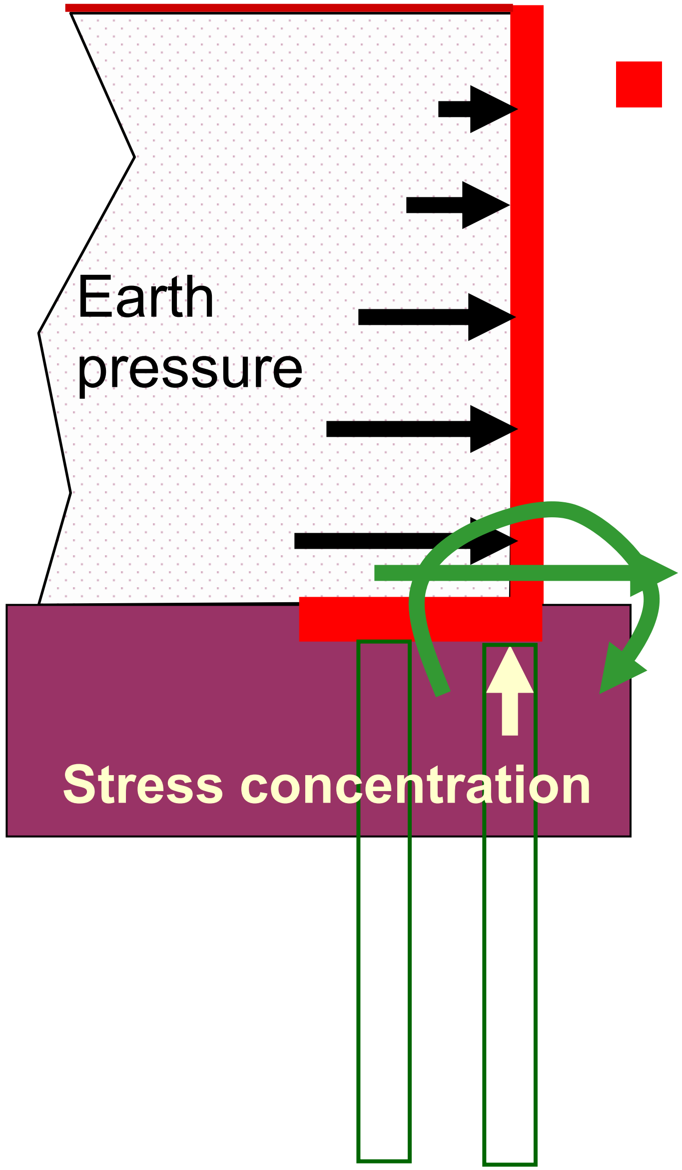
e) FHR facing

</td></tr>
</table>

The use of facing of discrete panels or modular blocks (i.e., **b** or **d**) decreases the wall deformation and increase the wall stability.

However, the use of **e) full-height rigid (FHR) facing** is much more effective for high wall stability and small wall deformation; and much more advantageous in many aspects.

Contents

First of all,
conventional type RW is a cantilever structure!

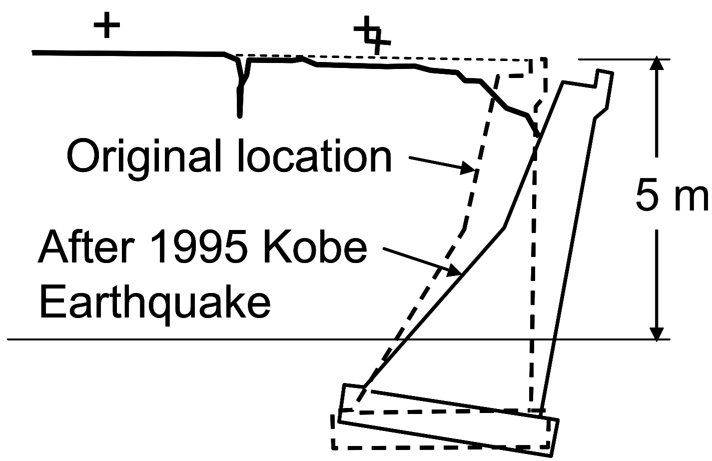


- Large forces in the facing, requiring massive & strong facing structure

- Large overturning moment & large lateral thrust load at the facing base,
resulting into large stress concentration at the facing base; & unstable behaviour, particularly by severe seismic loads.

So, usually a pile foundation is required.

Collapse of gravity walls (one type of cantilever RW) Ishiyagawa,1995 Kobe Earthquake



Dense gravelly subsoil & no pile

Overturning failure, in spite of seismic design using k_h= 0.2 with $(F_s)_{allowable}$= 1.5.

⇒ The conventional seismic design is not sufficient against severe seismic loads.

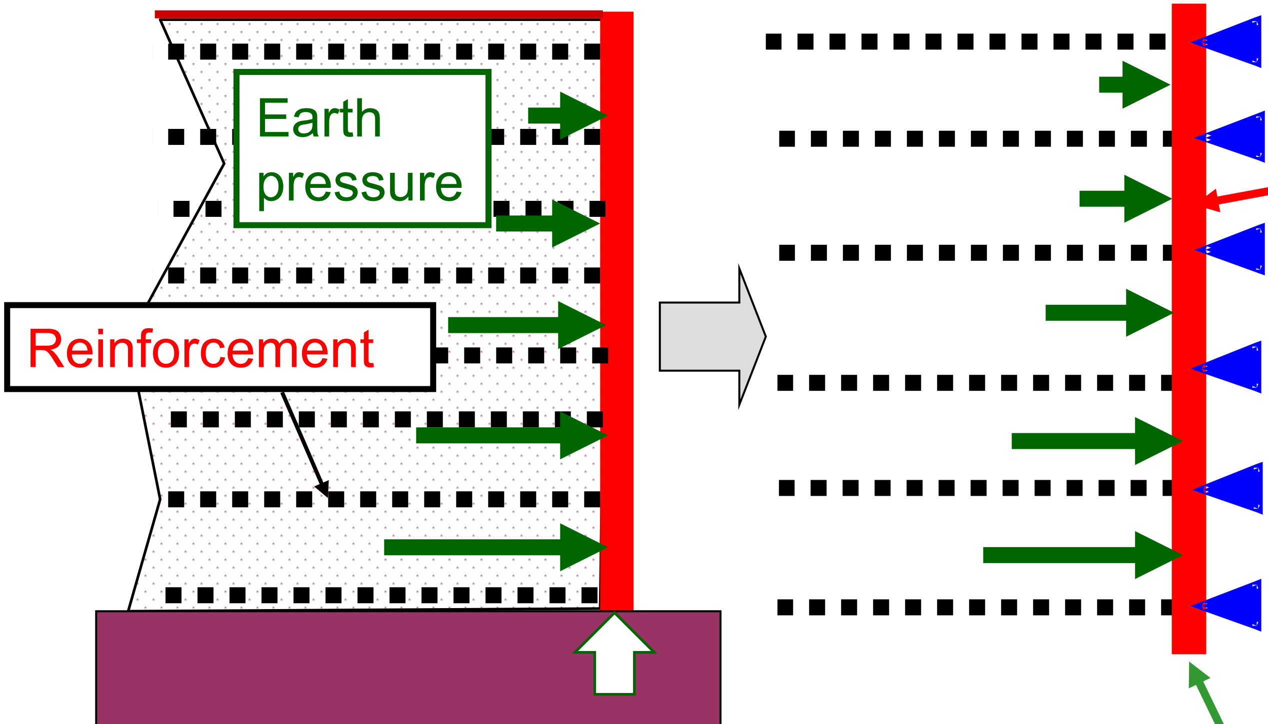
⇒ More stable wall type is required,

one of the solutions is

GRS RW with FHR facing

FHR facing for GRS RW is “a continuous beam supported by many reinforcement layers at a small span” - based on a mechanism that is utterly different from cantilever structures

⇒ several important advantages

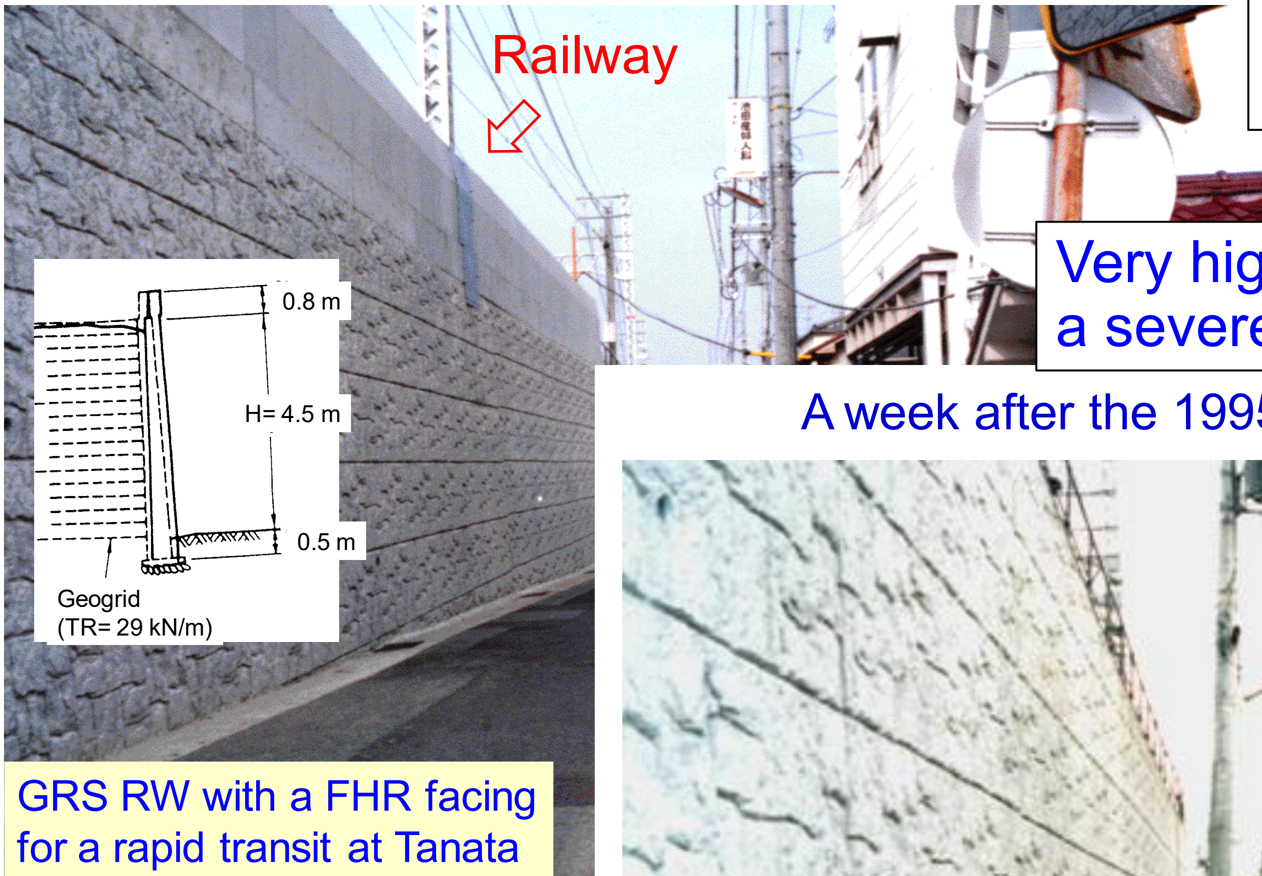


Very small forces in the facing, so a simple structure is sufficient

Small overturning moment & small lateral thrust load at the facing base ⇒
a pile foundation becomes unnecessary, and
the wall becomes stable even against severe seismic loads

GRS RW with FHR facing at Tanata

Immediately after completion, 1992



GRS RW with a FHR facing for a rapid transit at Tanata

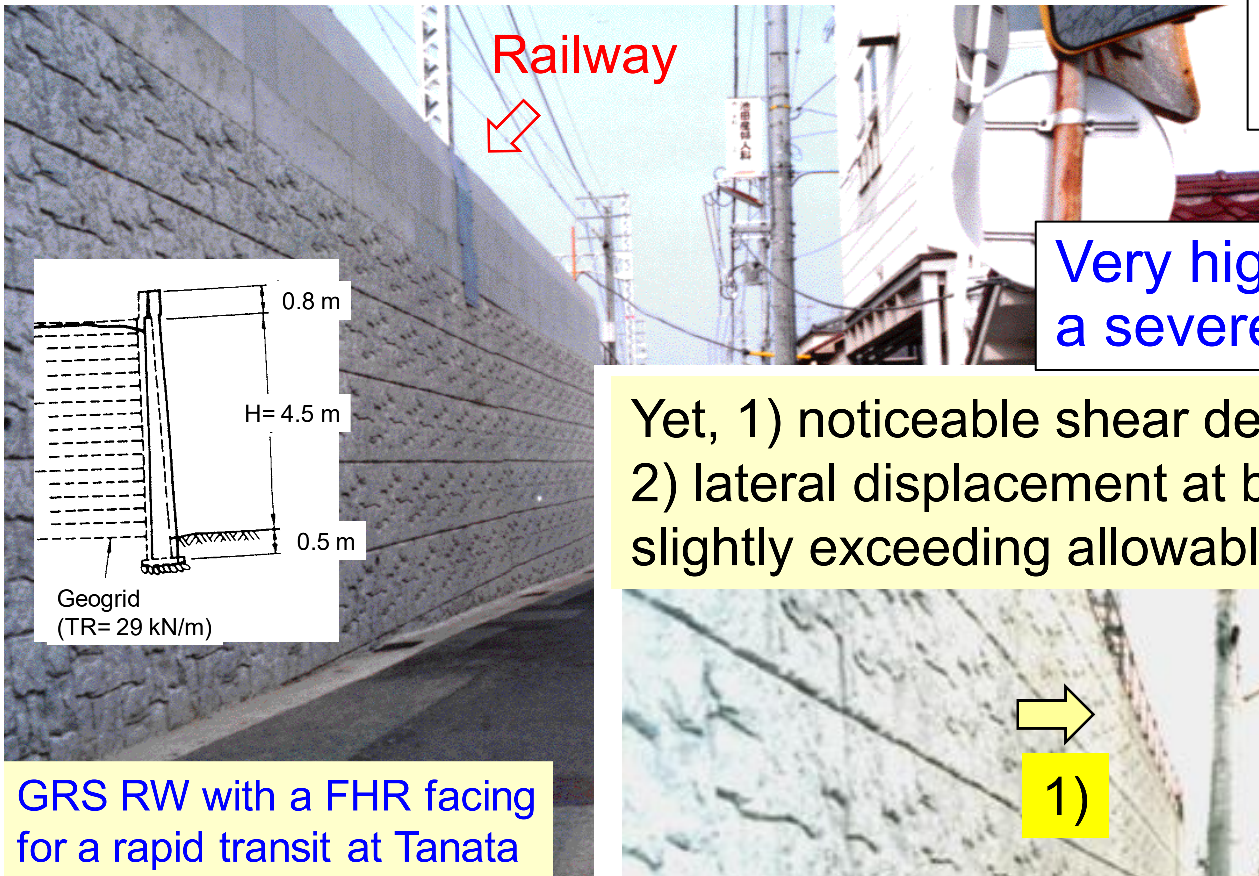
Very high performance during a severe earthquake

A week after the 1995 Kobe Earthquake

The wall survived!

GRS RW with FHR facing at Tanata

Immediately after completion, 1992



GRS RW with a FHR facing
for a rapid transit at Tanata

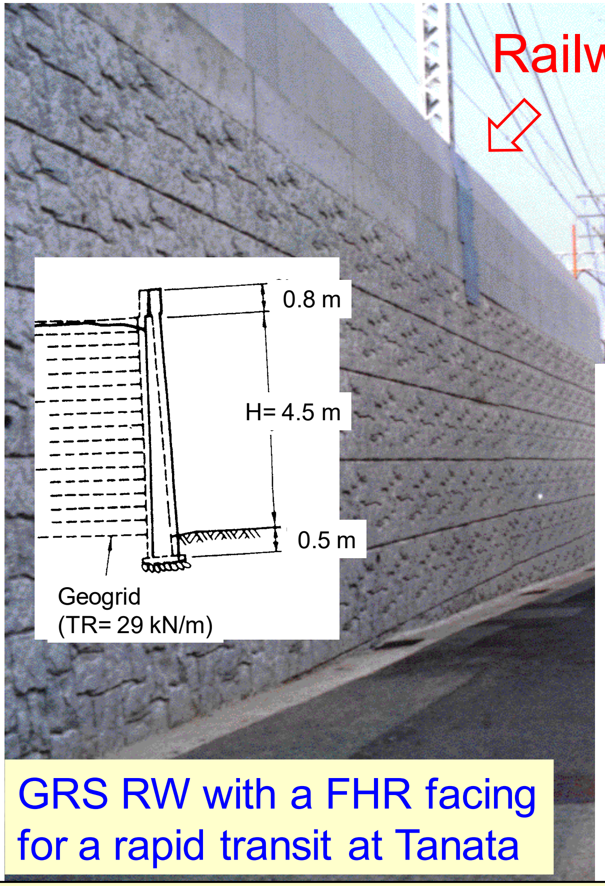
Very high performance during a severe earthquake

Yet, 1) noticeable shear deformation ≈ 2.7 %; &
2) lateral displacement at base d_B/H ≈ 2 %,
slightly exceeding allowable limit of wall deformation

The wall survived!

GRS RW with FHR facing at Tanata

Immediately after completion, 1992



GRS RW with a FHR facing for a rapid transit at Tanata

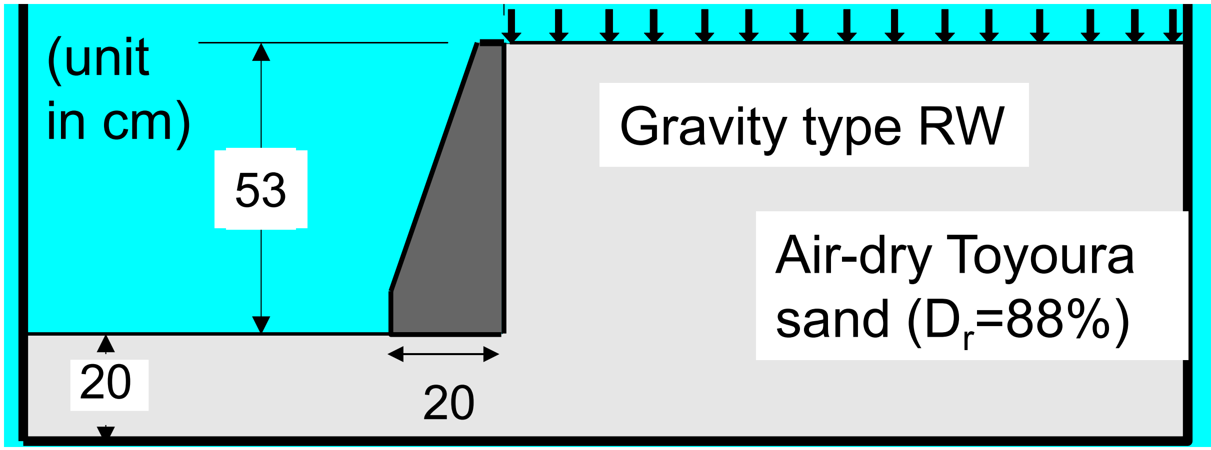
Very high performance during a severe earthquake

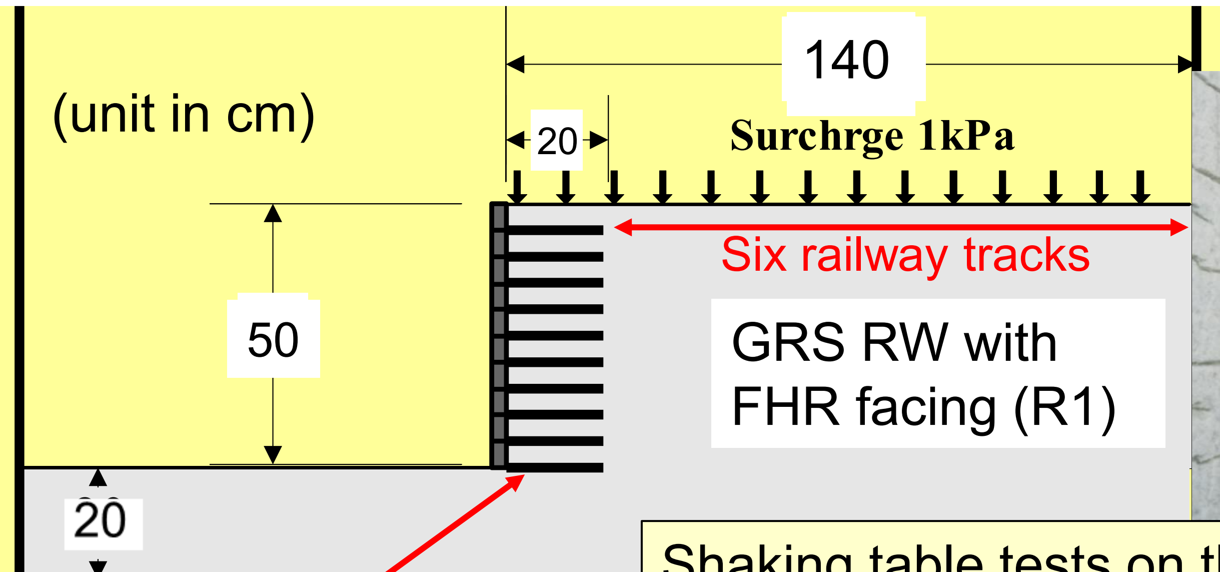
Yet, 1) noticeable shear deformation ≈ 2.7 %; & 2) lateral displacement at base $d_B/H \approx 2$ %, slightly exceeding allowable limit of wall deformation

This wall deformation was not large, but noticeable, which was due to that all the geogrid layers were short, only 2 m, 0.4 times the wall height H= 5 m.

⇒ This design was adopted as an exceptional case, because: a) the use of longer geogrid layers interacting with existing railway tracks on this wall was not allowed; and b) "$F_s \geq$ allowable minimum=1.5" was satisfied in the seismic design using k_h= 0.2 following the design code effective at the time of the design of this wall.

Shaking table tests simulating RWs during the 1995 Kobe E.Q.



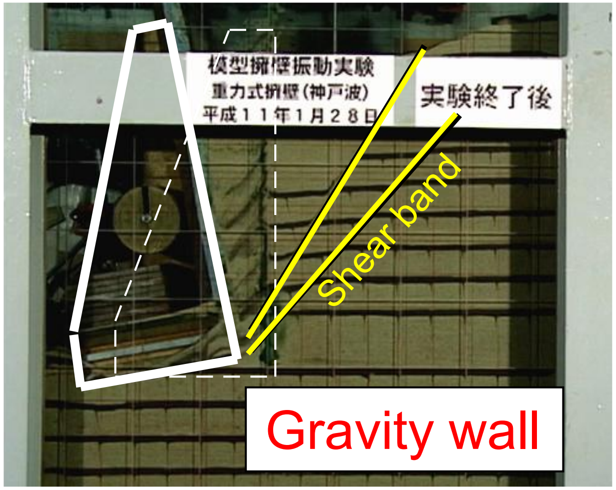


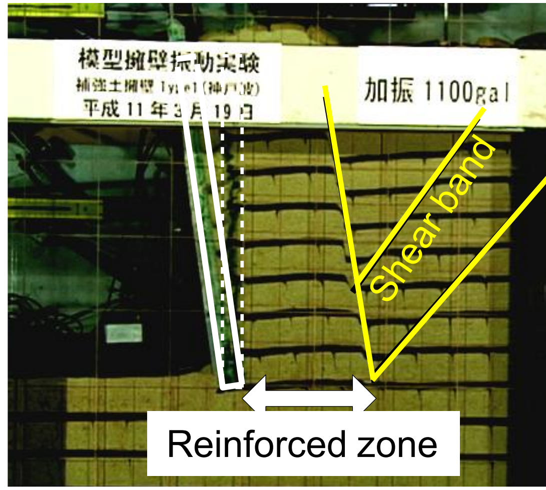
Reinforcement (10 layers): grid of phosphor-bronze strips (t=0.2mm)

(Koseki et al., 2008)

Shaking table tests on these & other wall models to:

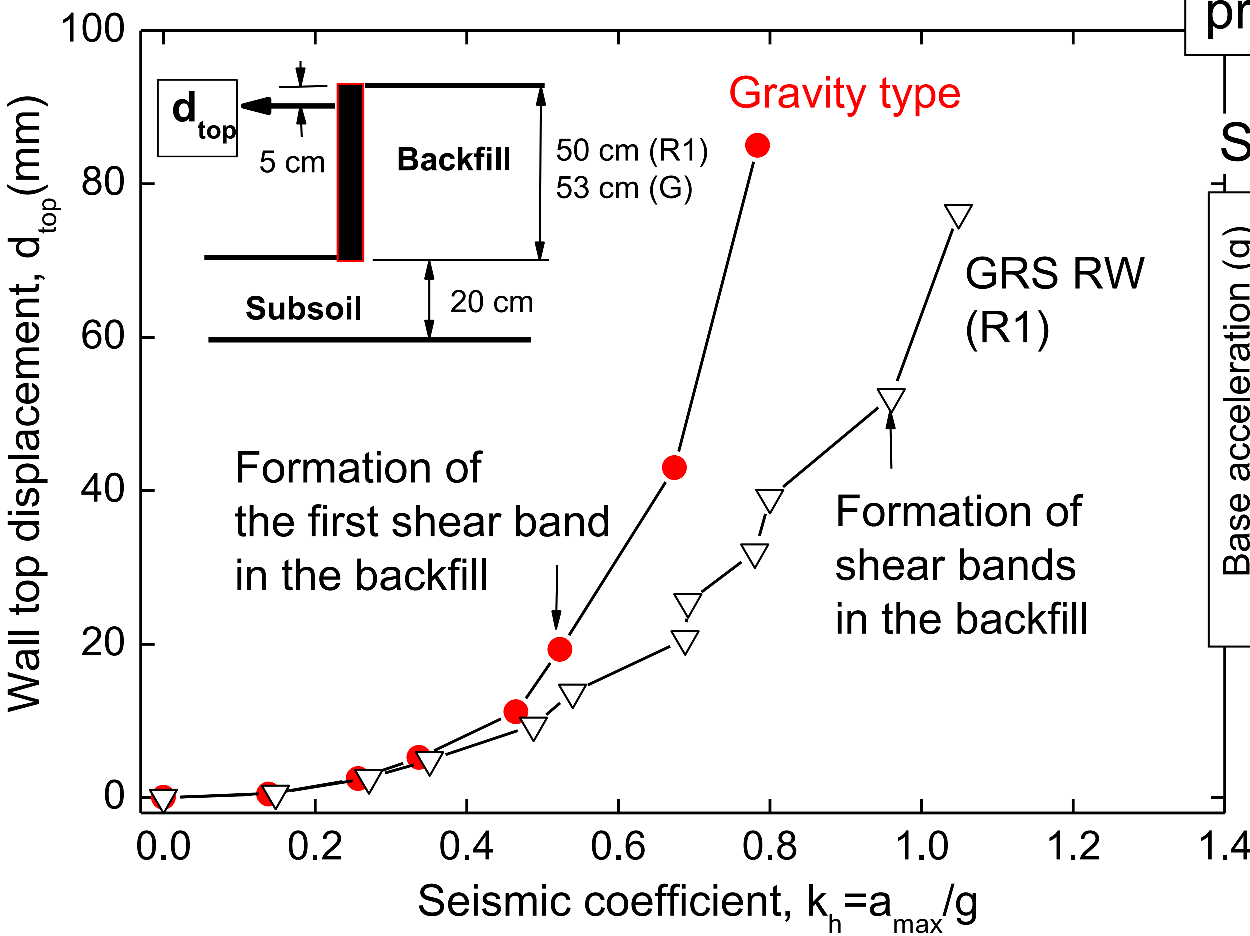
1) confirm a high seismic stability of GRS RW with FHR facing; and
2) find the necessary & sufficient geogrid length to ensure high stability against high seismic load.



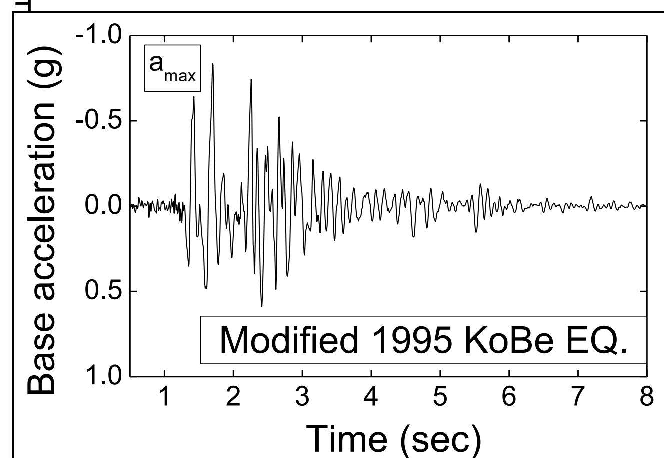


⇐ GRS RW (R1): noticeably more stable than the gravity wall.

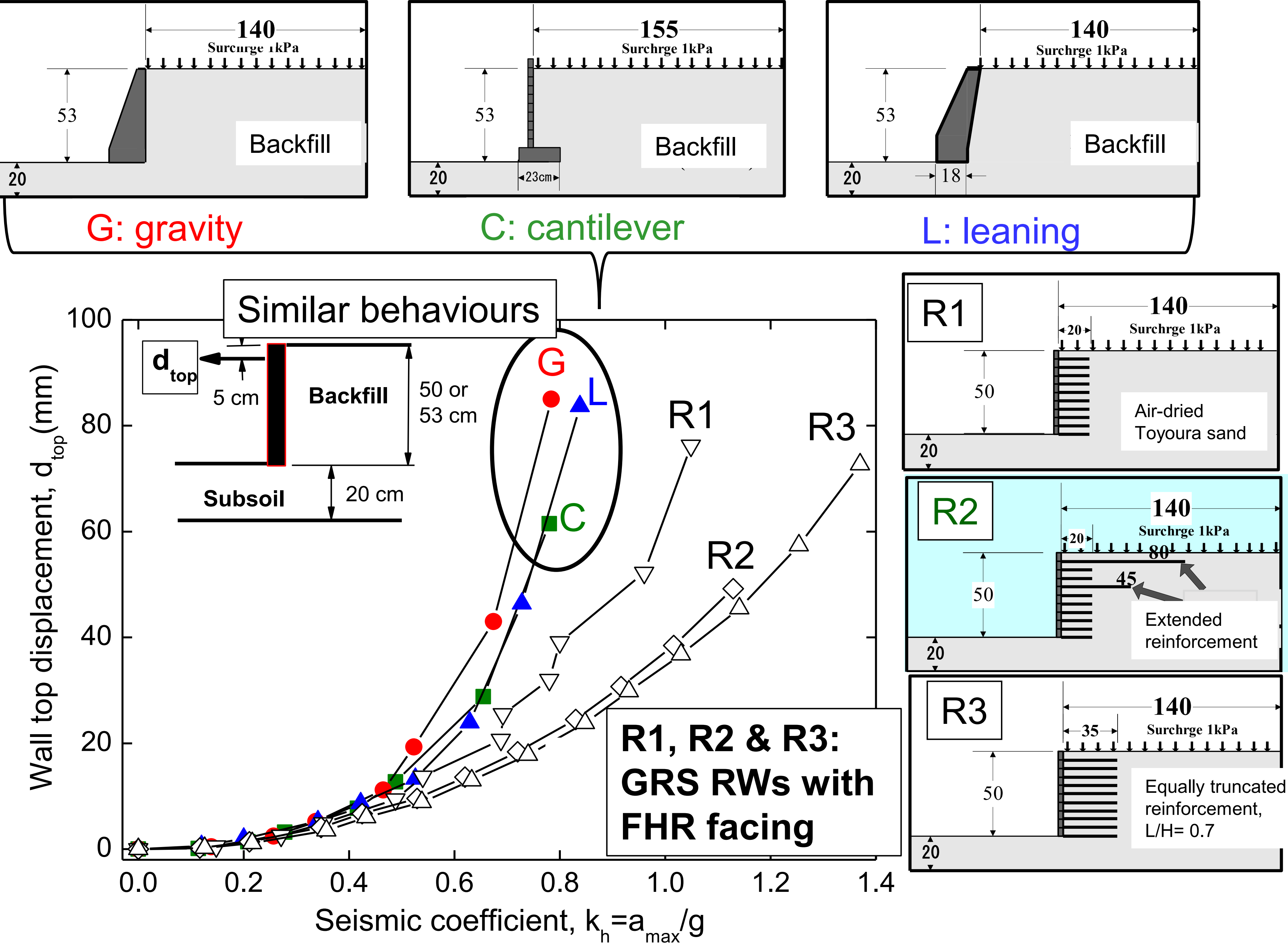
The behaviours of these two model RWs are consistent with those of the prototype walls.



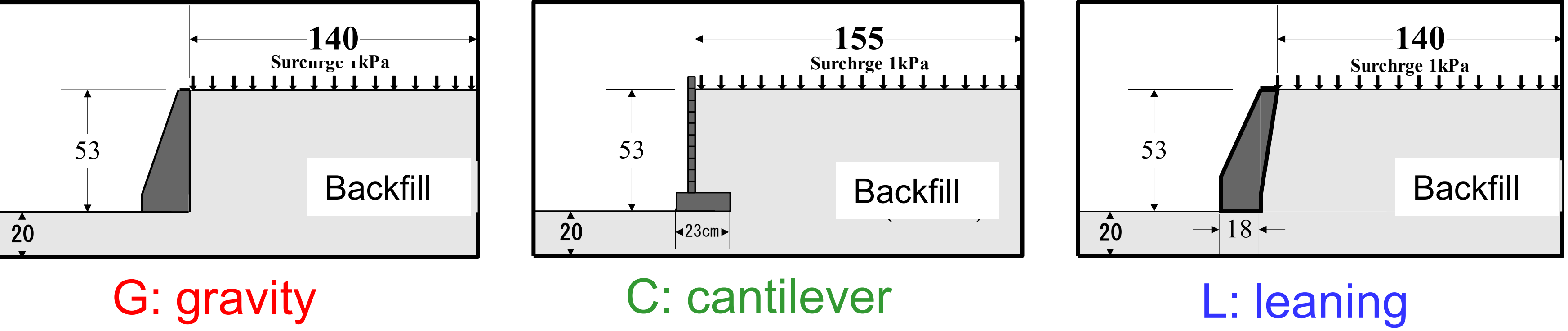
Step-wise increase in α_{max}

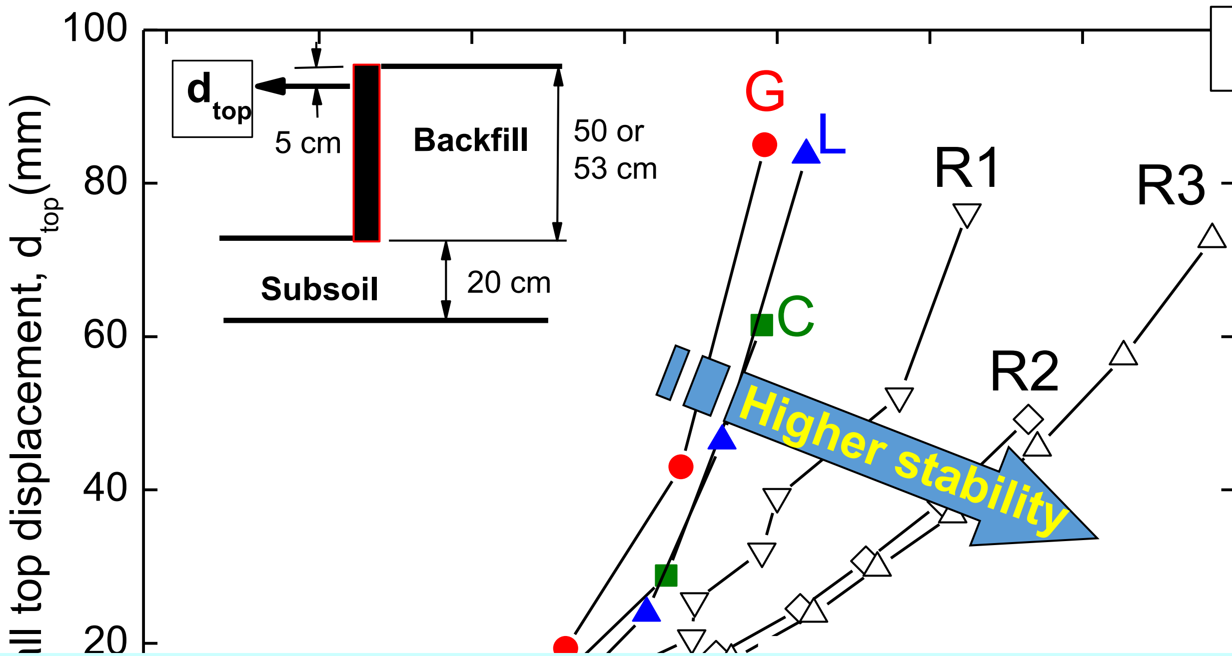


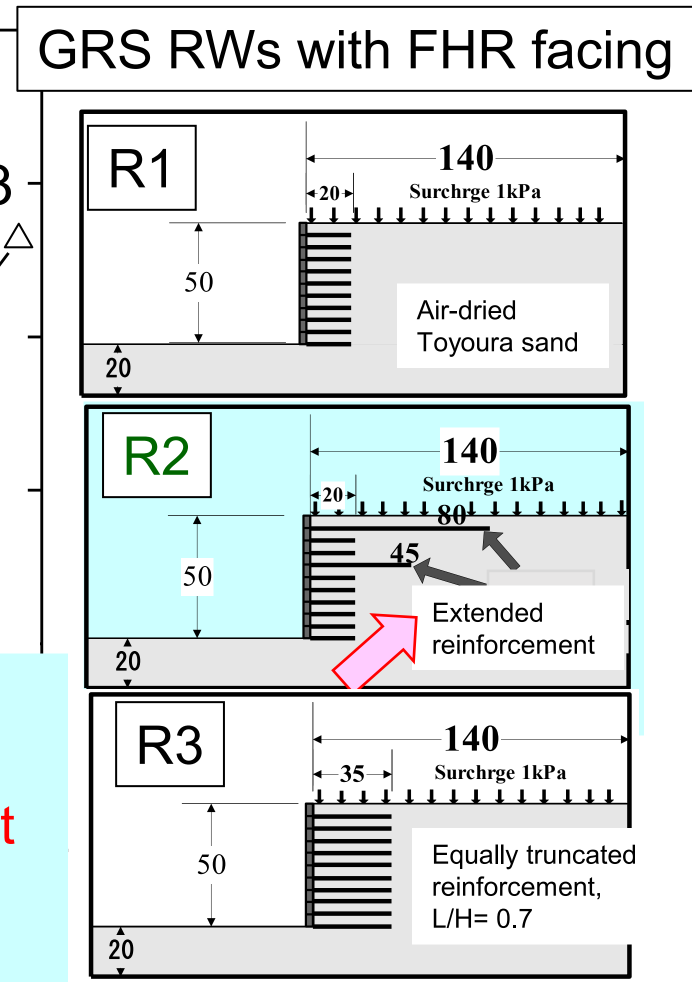
Koseki, J., Tateyama, M., Watanabe, K. and Nakajima, S. 2008. Stability of earth structures against high seismic loads, Keynote Lecture, *Proc. 13th ARC on SMGE*, Kolkata, Vol. 2, pp.222-241.



(Koseki et al., 2008)



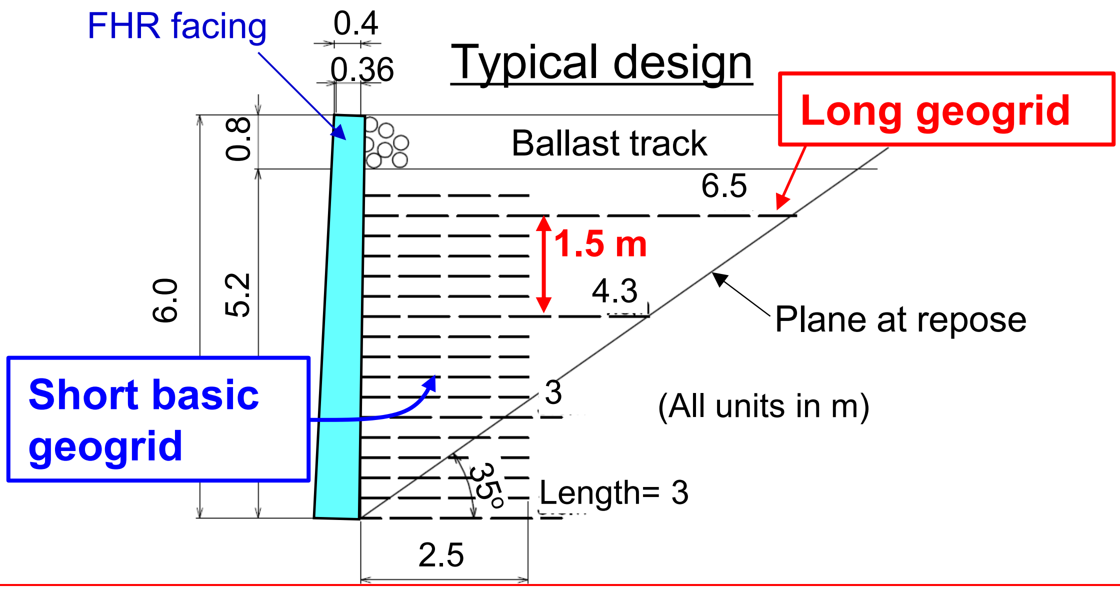




R2: a higher stability than R1 & similar as R3, whereas more cost-effective than R3 because of: 1) a less amount of geogrid; and 2) a less amount of excavation when constructed on a slope

⇒ R2 is the standard type in the current design.

Typical arrangement of geogrid layers in R2 type GRS RW



In addition to the short basic geogrid layers at a vertical spacing of 0.3 m, long geogrid layers extended to the plane of repose are arranged at a vertical spacing of 1.5 m.

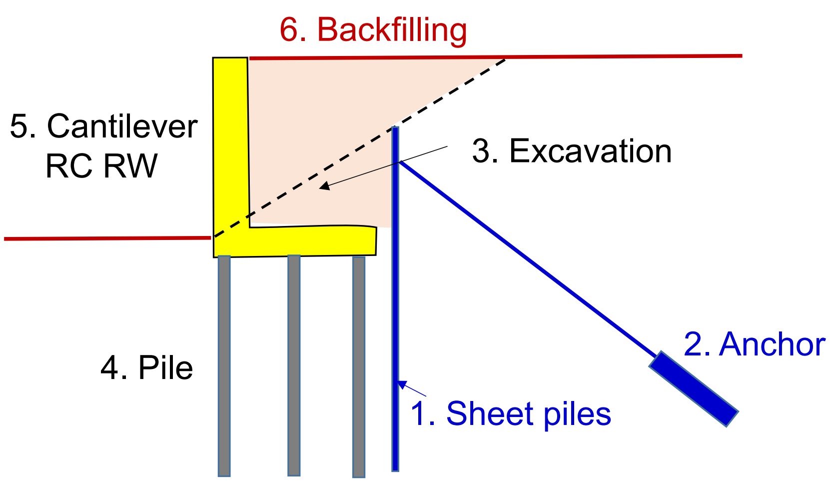
Why the basic geogrid layers are required to be short ?
⇒ next pages….

<u>Gentle slopes are often re-constructed to vertical walls, particularly in urban areas</u>

⇒ However, the two reconstruction methods shown below are costly & needs a long construction period due to:

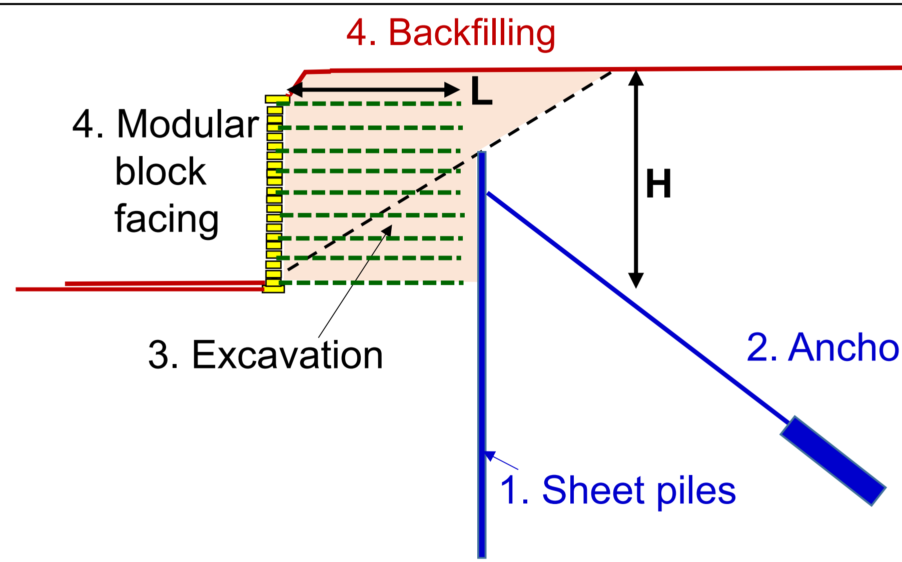
- large slope excavation; and
- the use of temporary support, such as anchored sheet piles

Conventional cantilever RW



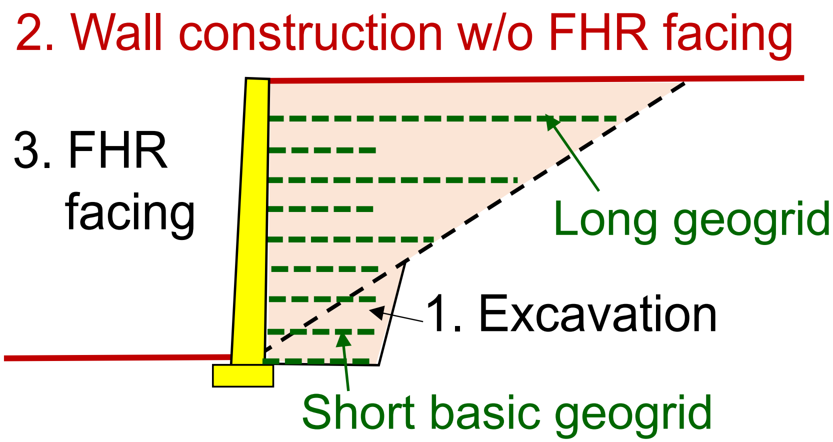
Large excavation due to a relatively wide base of cantilever RW

MSE RW having facing of discrete panels or modular blocks (not a solution)



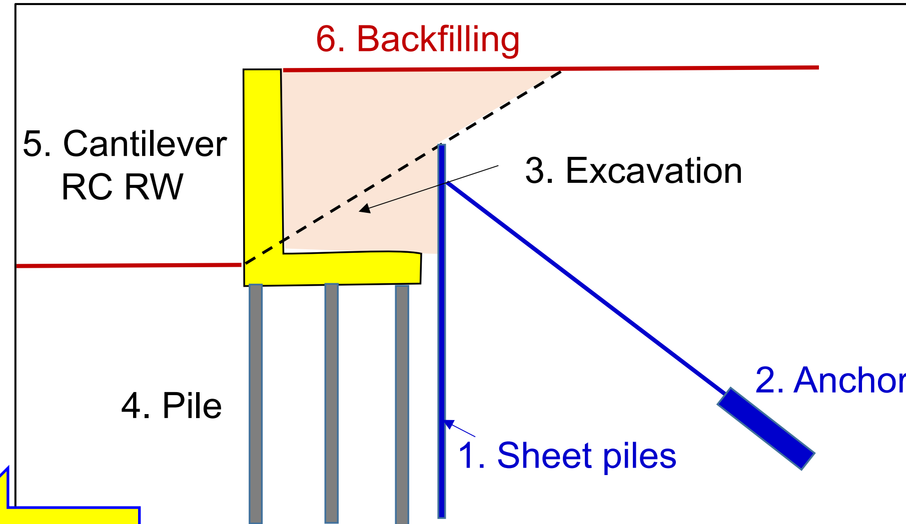
As the facing is discrete, the use of relatively long reinforcement (usually L/H> 0.7) is required for sufficient wall stability.

GRS RW with FHR facing is a solution !

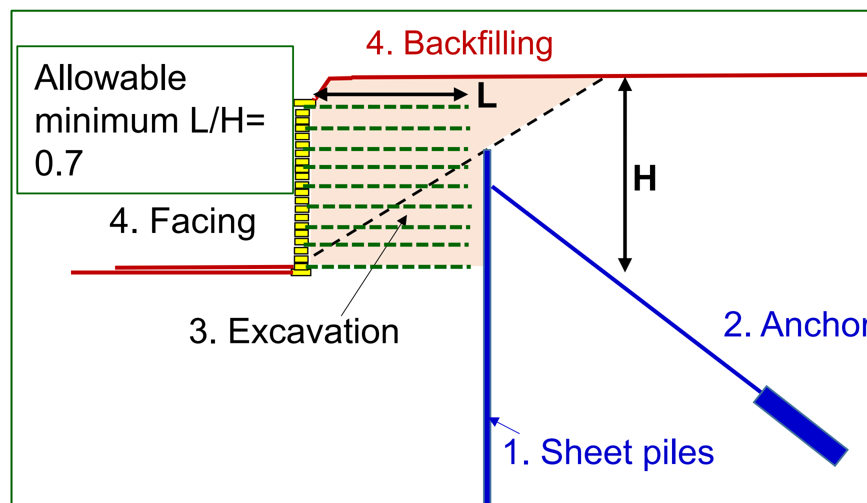


Reduced slope excavation and no use of anchored sheet piles

Conventional cantilever RW

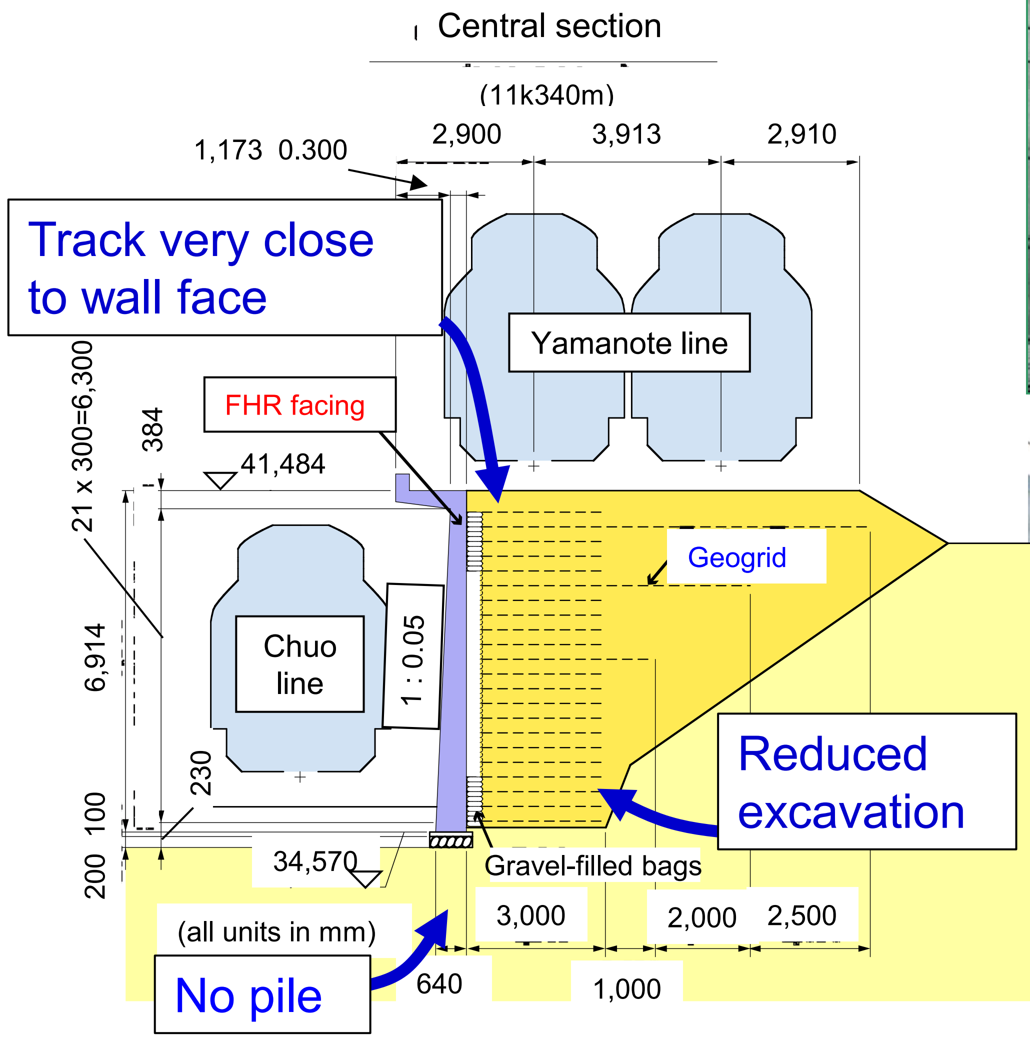


MSE RW having facing of discrete panels or modular blocks and using relatively long geogrid layers

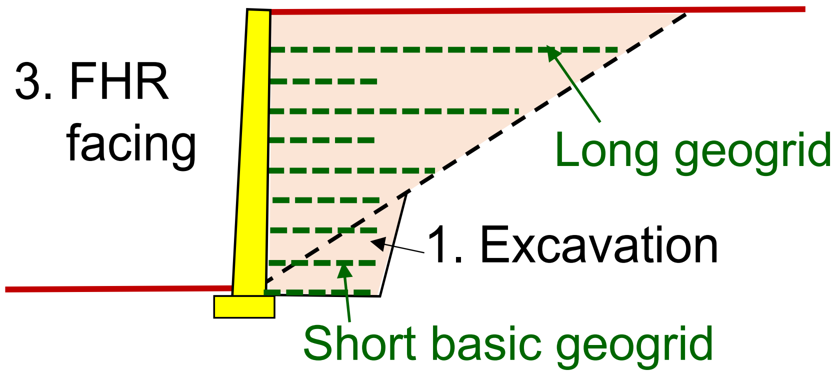


GRS RW with FHR facing supporting a commuter railway

Near Shinjuku Station, Tokyo, constructed during 1995 – 2000



GRS RW with FHR facing

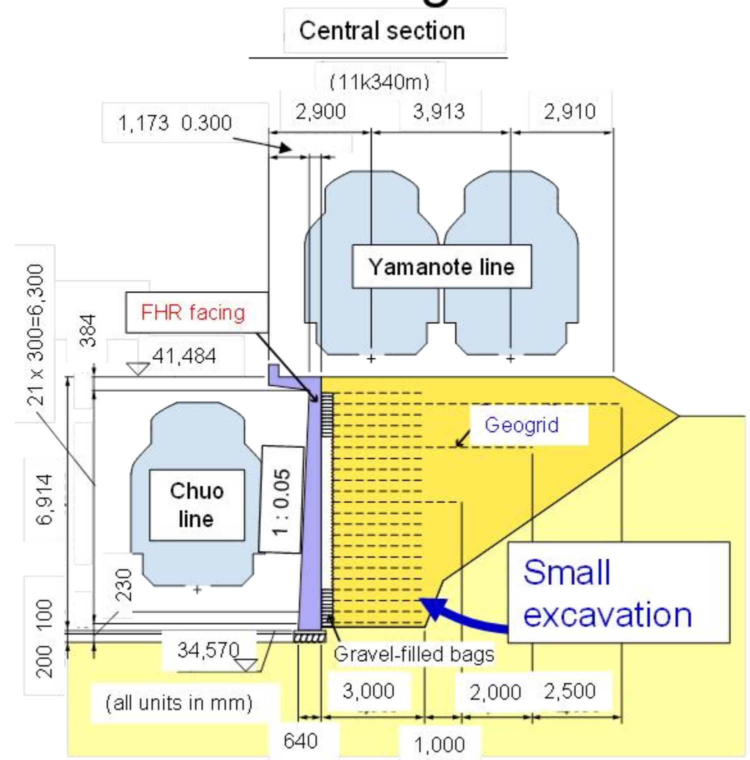


Reduced slope excavation & no use of anchored sheet piles.

Reduction in the wall stability by the use of short basic geogrid layers is covered by the use of:

1. densely arranged planar geogrid layers having high pull-out strength;
2. several long geogrid layers; &
3. FHR facing designed to be strong & stable enough against earth pressure & external loads.

Near Shinjuku Station, Tokyo, constructed during 1995 – 2000

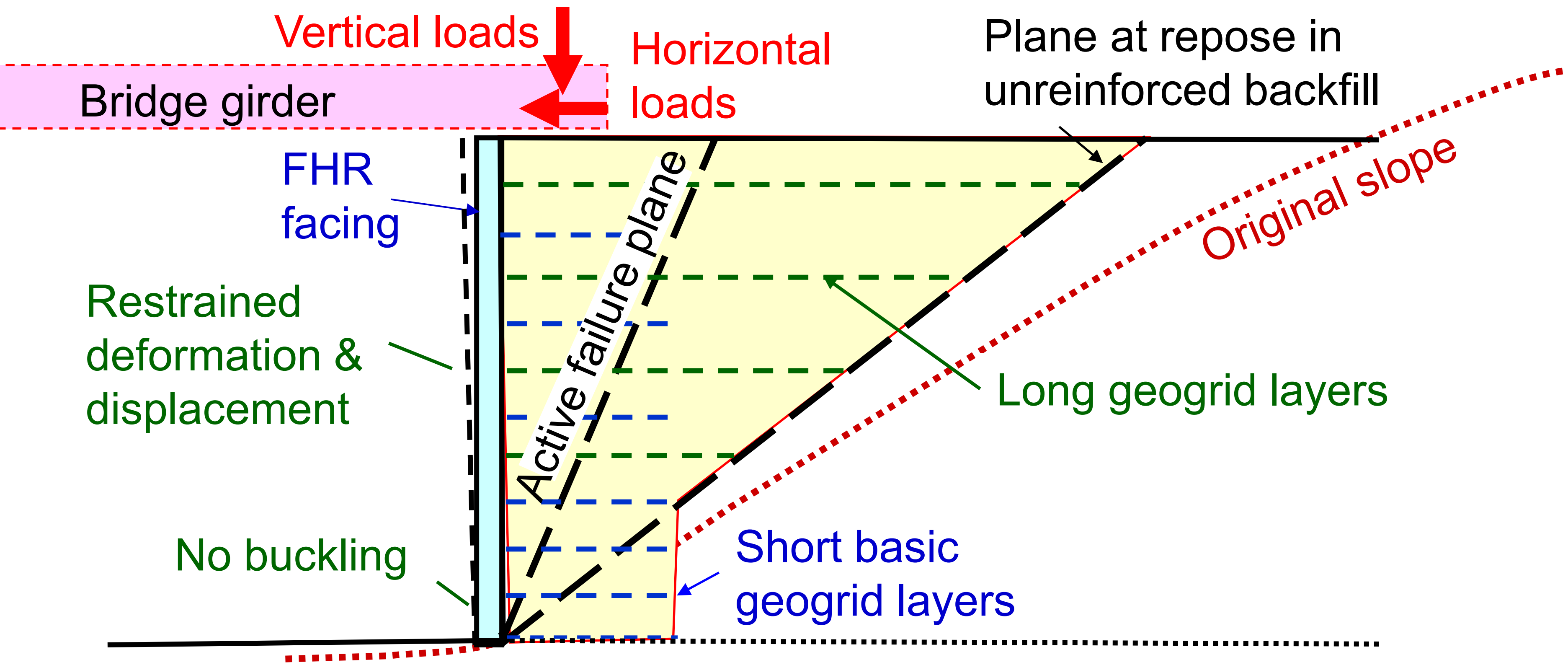


“**The use of: 1) dense geogrid layers; 2) several long geogrid layers; and 3) FHR facing**” enhances monolithic behaviour of the enlarged reinforced zone without developing local internal failure!

⇒ Increase in the wall stability against over-turning, lateral sliding and shear deformation caused by:

a) backfill earth pressure (particularly seismic earth pressure), and

b) external loads at or near the FHR facing !



"**The use of: 1) dense geogrid layers; 2) several long geogrid layers; and 3) FHR facing**" enhances monolithic behaviour of the enlarged reinforced zone without developing local internal failure!

⇒ Increase in the wall stability against over-turning, lateral sliding and shear deformation caused by:

a) backfill earth pressure (particularly seismic earth pressure), and

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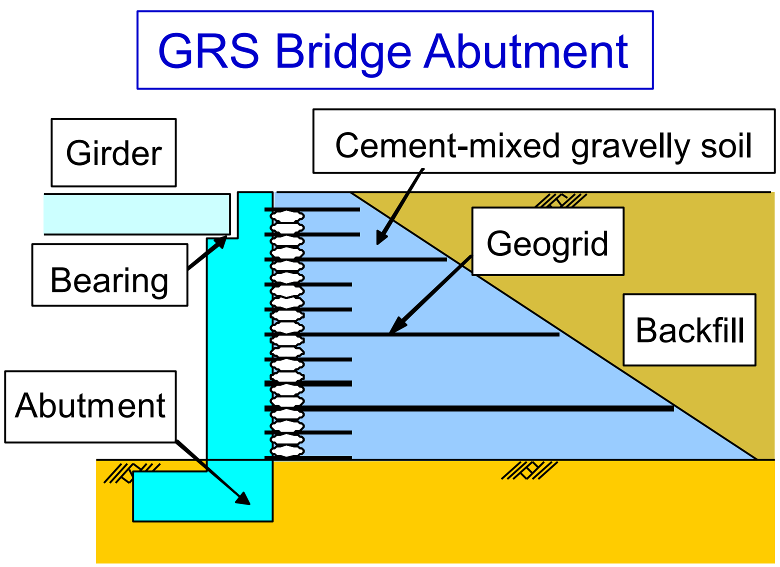
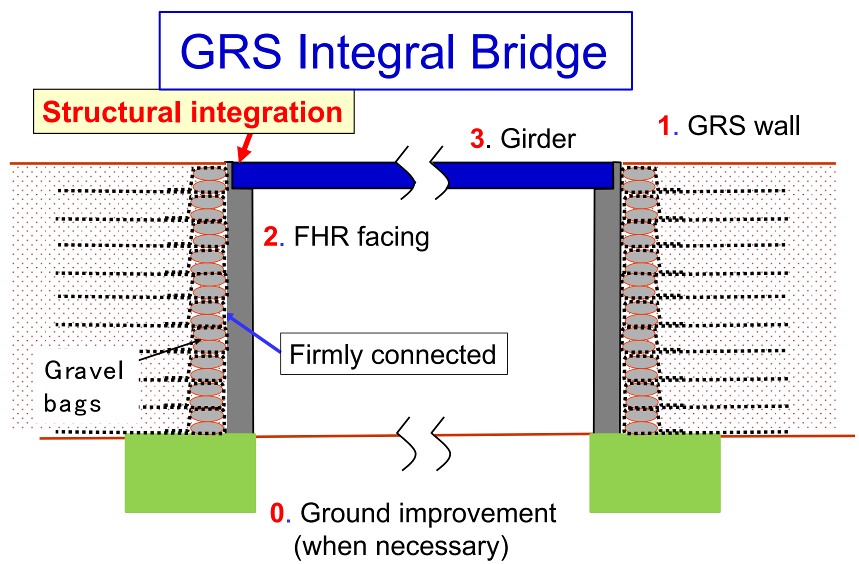
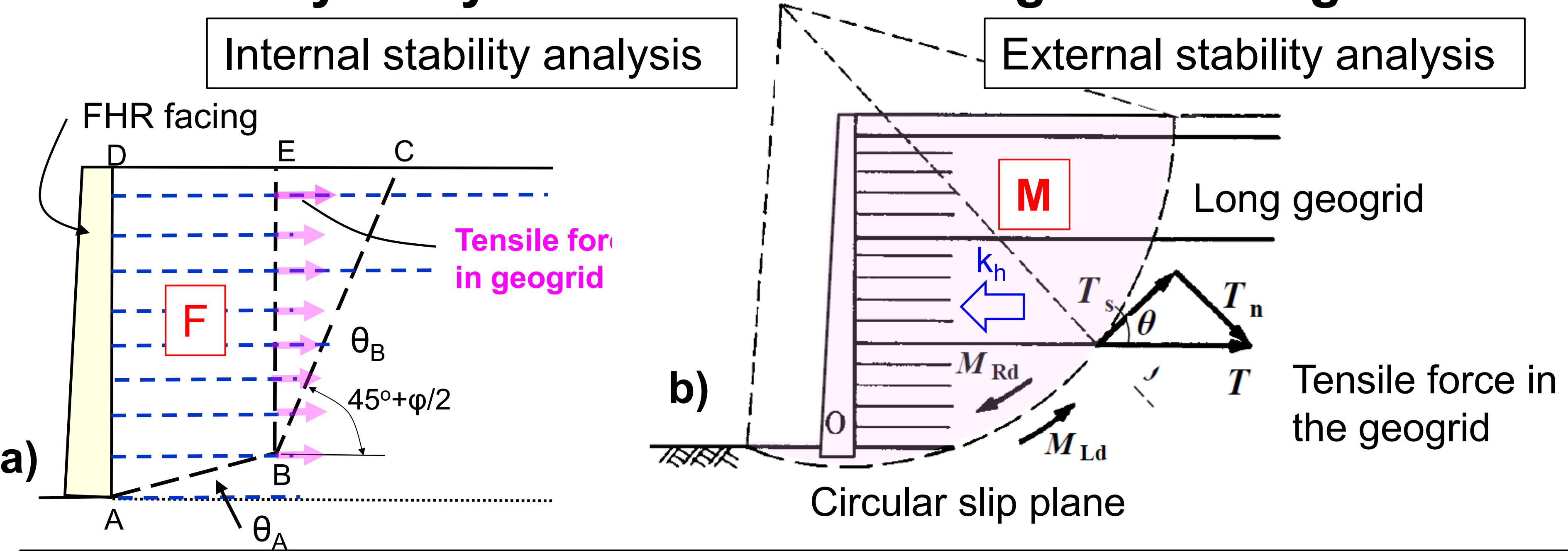
⇒ Developments of…..



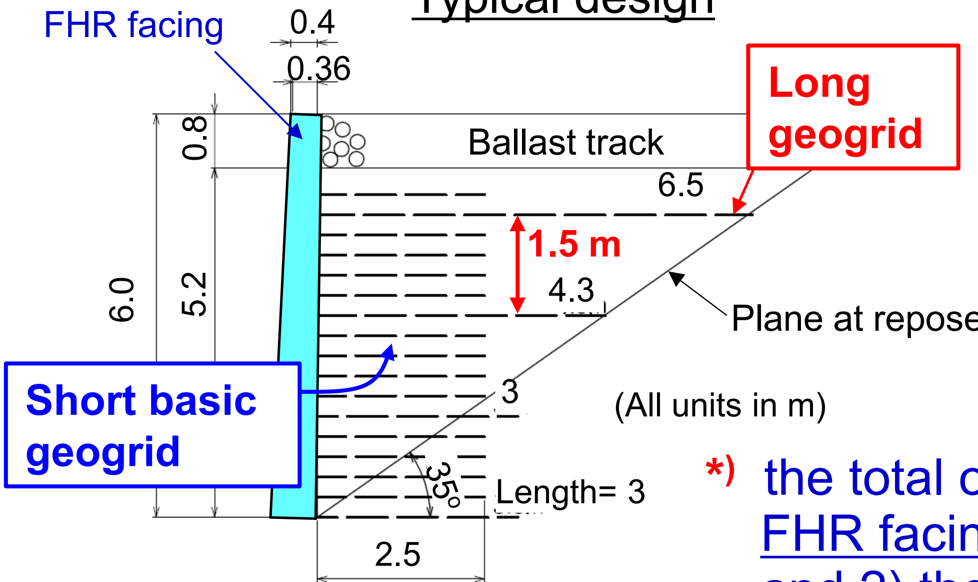


Stability analysis of GRS RW having FHR facing:



- The length of short basic geogrid is determined by the internal stability analysis (Fig. a).

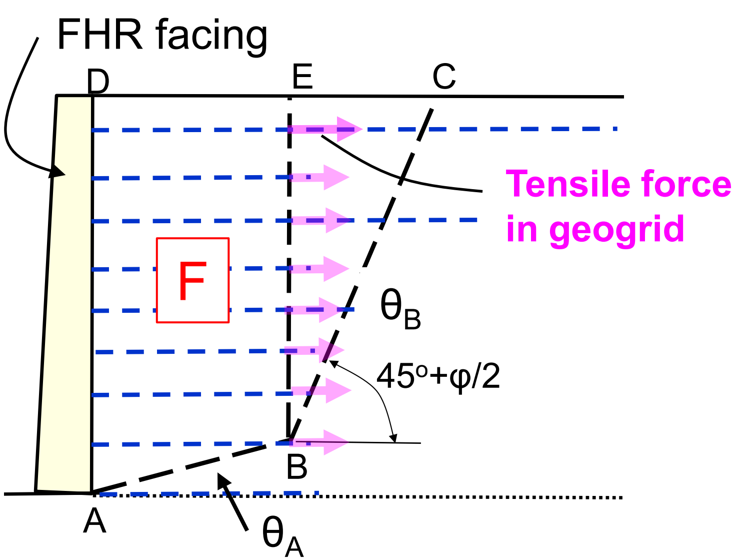
Typical design



The length of the basic geogrid layers is the largest value among:
1) 35 % of wall height;
2) 1.5 m; and
3) the length required to keep iwall deformation*) lower than allowable value against level 2 design seismic load.

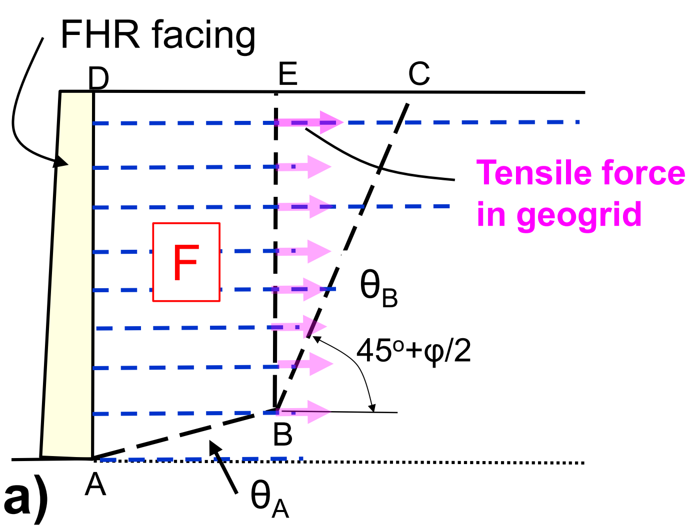
*) the total of 1) "the monolithic displacement of FHR facing plus front wedge F by over-turning and 2) the one by lateral sliding, each separately evaluated by the Newmark method based on the TW stability analysis; and 3) "shear deformation of reinforced zone evaluated by strain energy analysis".

Two-wedge analysis for internal stability:

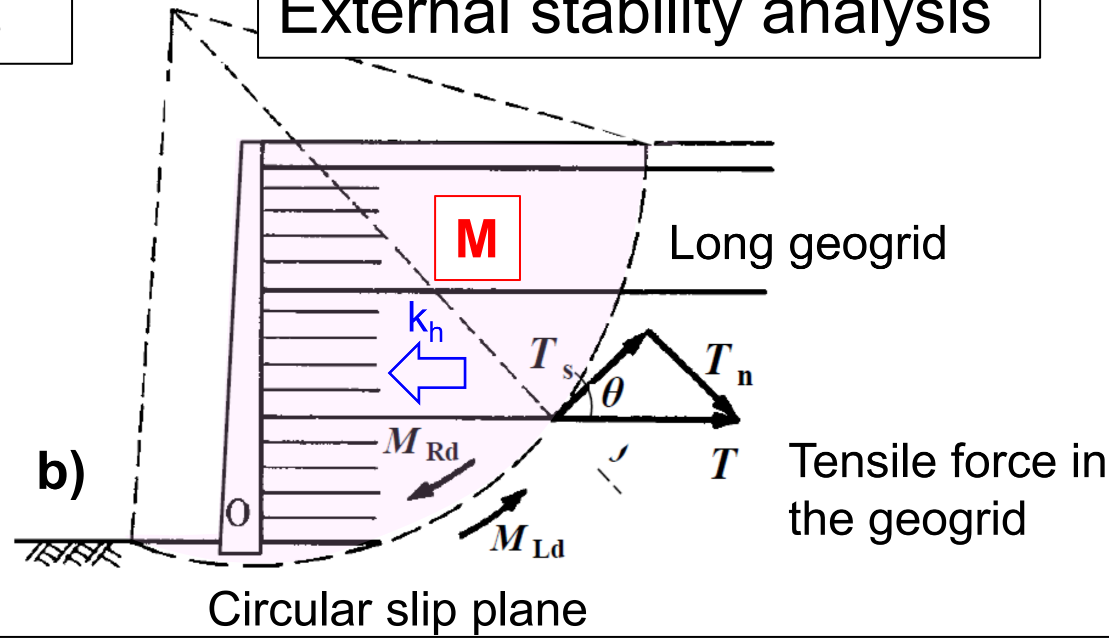


The stability of the FHR facing and front wedge F as a unified unit is examined for all possible locations of point B and all possible angles θ_A & θ_B of TW failure planes. With RR GRS RWs, point A is always at the heel of the footing of FHR facing, which largely increases the wall stability.

Internal stability analysis



External stability analysis



- The length of short basic geogrid is determined by the internal stability analysis (Fig. a).
- As part of the internal stability analysis, the FHR facing is designed to be strong and stable enough against the internal forces in the FHR facing developed by the earth pressure and external loads.

- Then, the external stability is confirmed by the circular slip stability analysis using a horizontal seismic coefficient k_h (level 1) (Fig. b).

In the ordinary cases, the length of short basic geogrid is determined by the internal stability analysis. When the supporting subsoil is relatively weak or when the wall is located on a slope, basic geogrid layers required for sufficient external stability may become longer than those required for internal stability.

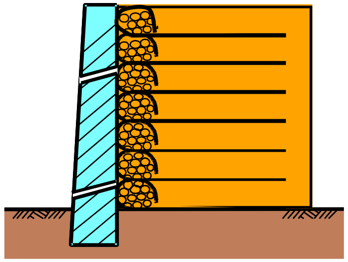
Multiple functions of FHR facing (summary)

1) The facing is the important and **essential structural component** to:

   a) confine the backfill by developing large tensile forces in the reinforcement; and

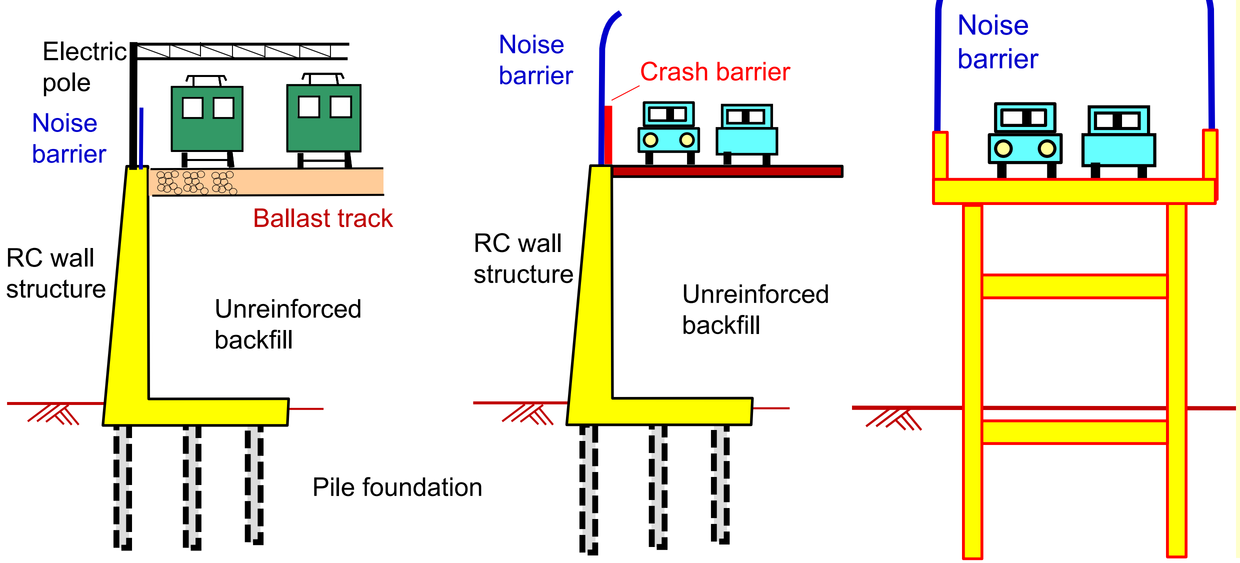
   b) support other structures.

   So, **during service,** the facing should be **stiff enough**.



Full-height rigid facing

Conventional RWs & RC viaduct



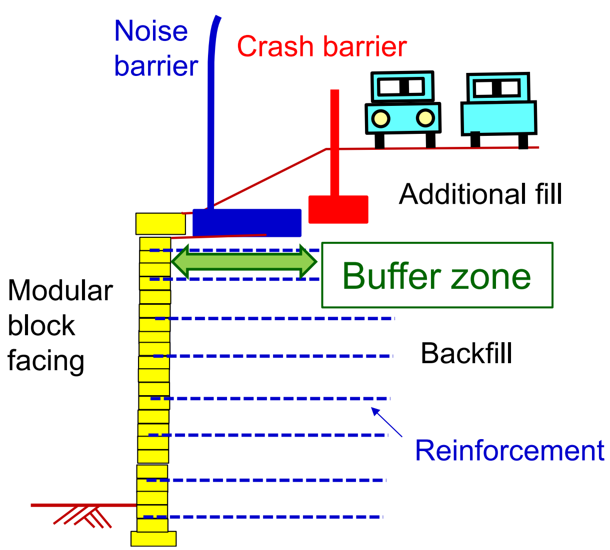
<u>Disadvantages</u>

Costly

<u>Advantages</u>

- Limited occupied space
- Ability to support other structures

GRS RWs with facing of modular blocks or discrete panels

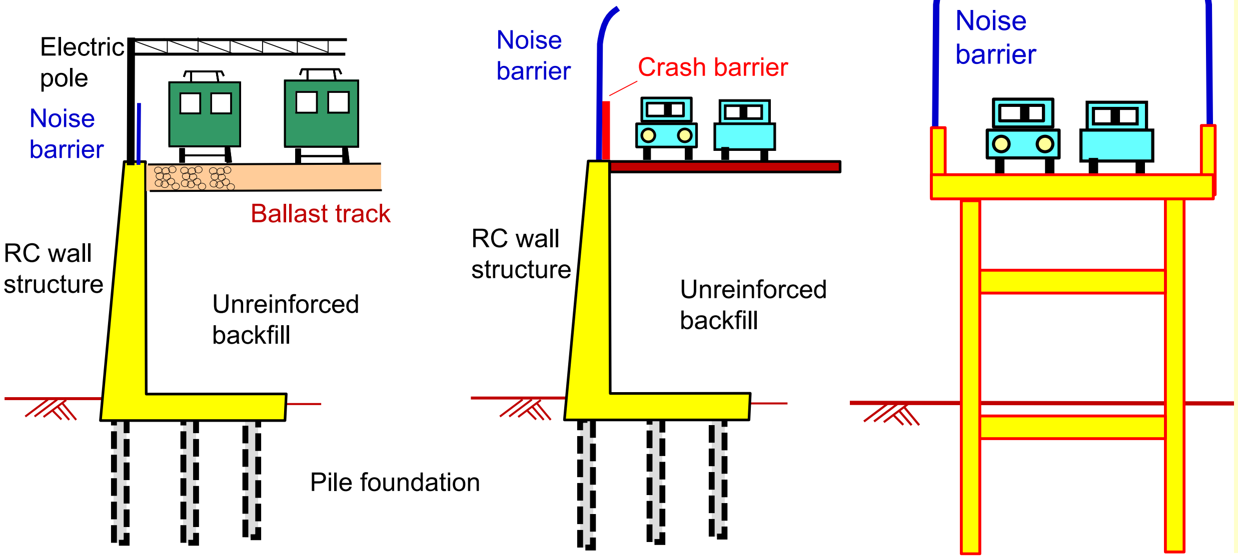


Less costly,

but, <u>unlike conventional RWs & RC viaduct</u>,

- a buffer zone is required to ensue the safe operation of road & railway, so wider occupied space required; and
- the facing cannot effectively support other structures

Conventional RWs & RC viaduct



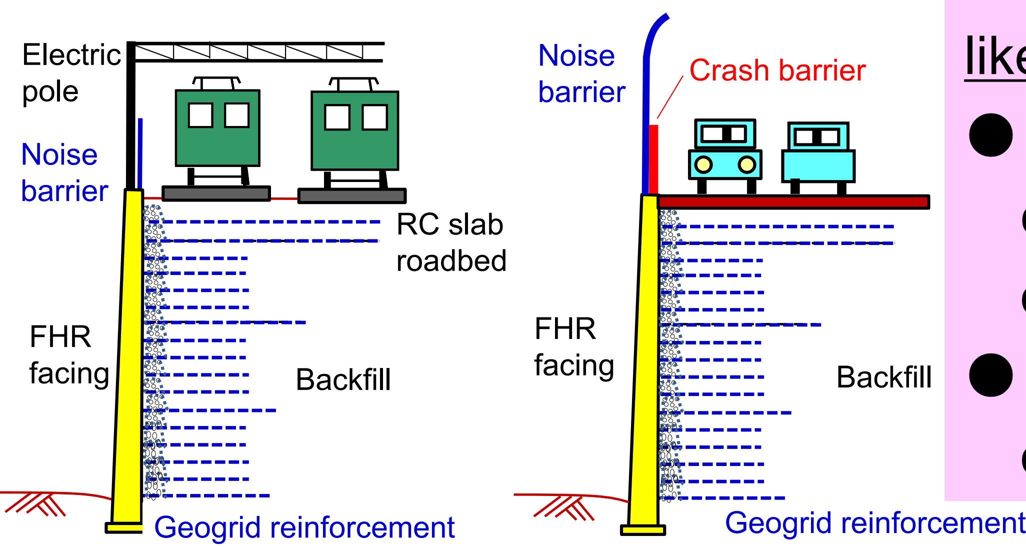
<u>Disadvantages</u>

Costly

<u>Advantages</u>

- Limited occupied space
- Ability to support other structures

GRS RWs with FHR facing



Less costly; and,

<u>like conventional RWs & RC viaduct,</u>

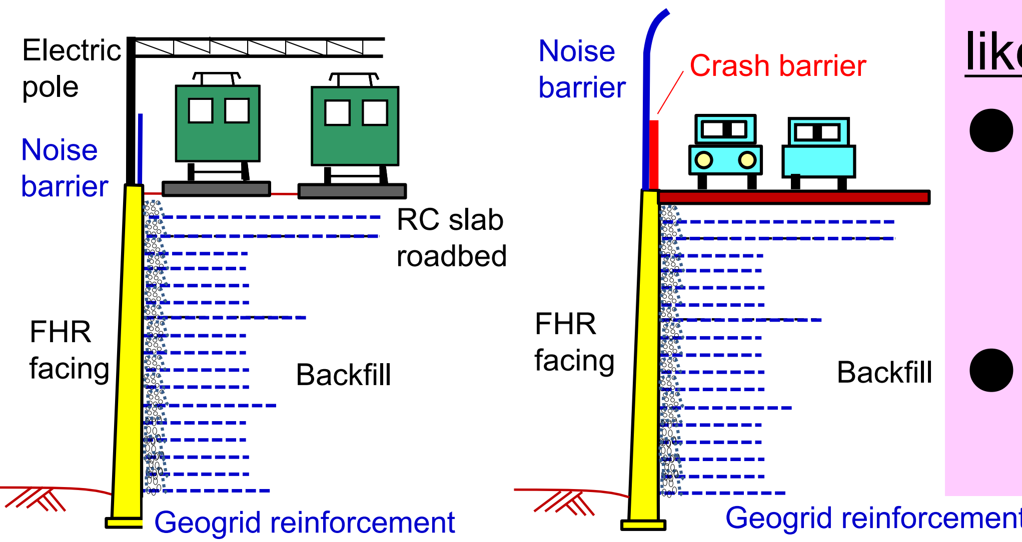
- railway & road can be arranged very close to the wall face, so smaller occupied space; and
- FHR facing can effectively support other structures.

JR Kobe line, Amagasaki

Electric supply structure supported by FHR facing

Track located very close to wall face

GRS RWs with FHR facing



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1) The facing is the important and **essential structural component** to:

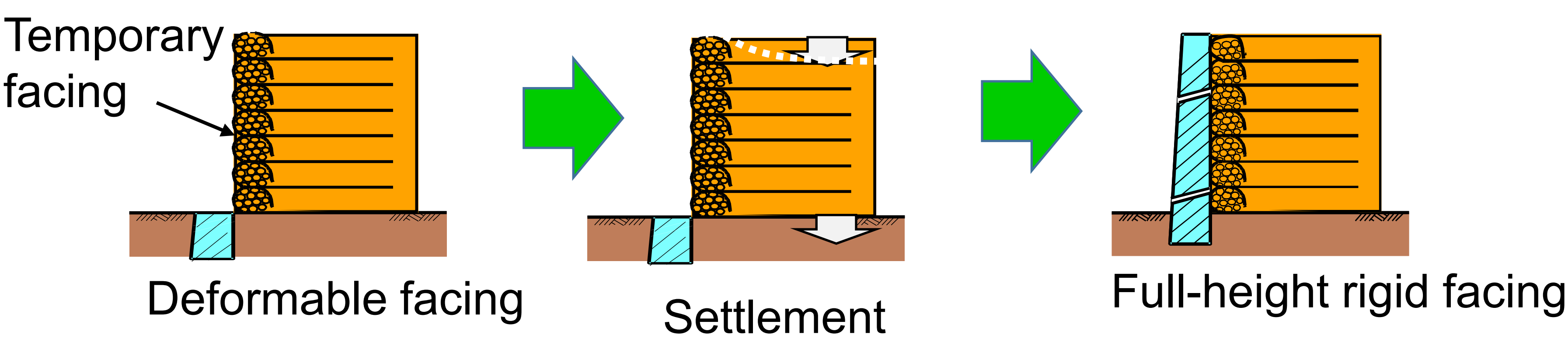
   a) confine the backfill by developing large tensile forces in the reinforcement; and

   b) support other structures.

   So, **during service**, the facing should be **stiff enough**.

2) **During the construction of reinforced backfill**, the facing should be not only strong enough but also **deformable enough to accommodate the deformation of backfill & subsoil**.

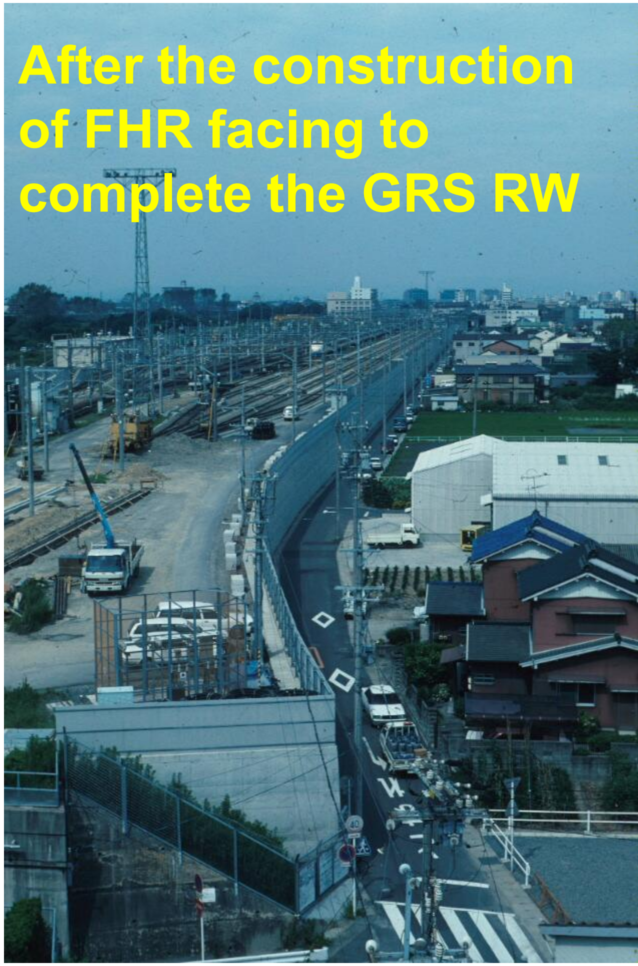
This contradiction can be solved by staged-construction.



Contents

Staged construction of GRS RW with FHR facing

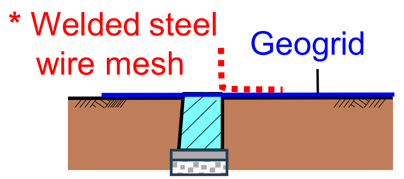
Depot for HSR (Shinkansen) at Biwajima, Nagoya, 1989 - 1990
- average wall height= 5 m & total length= 930 m



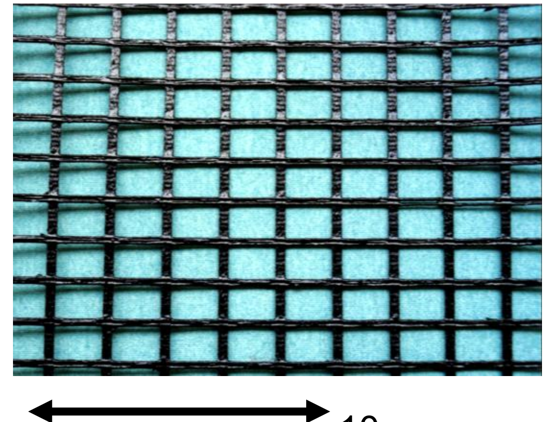
Staged construction: 1) & 2)

- Start of construction

1) Levelling pad & embedded part of FHR facing



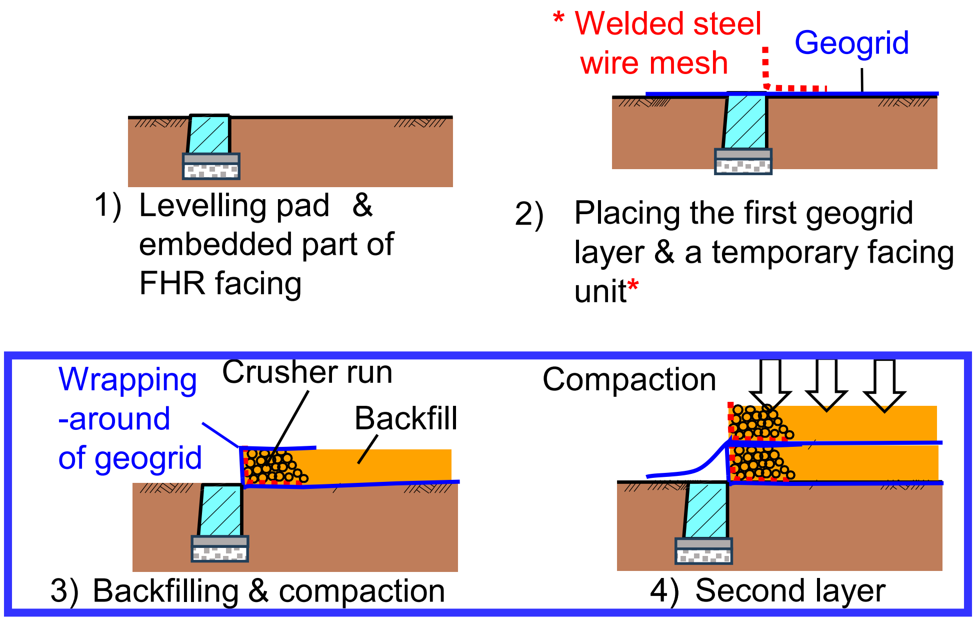
2) Placing the first geogrid layer & a temporary facing unit*



Typical polymer geogrid: bi-axial PVA grid:

Staged construction: 3) & 4)

- Compaction of the backfill with a help of temporary facing units placed at the shoulder of each soil layer



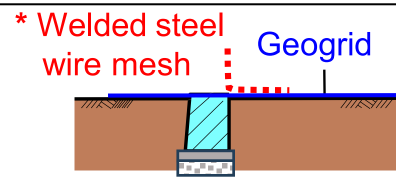
Good compaction of the backfill is achieved by:

1) a small lift (15 cm) ensured by a small vertical spacing (30 cm) between geogrid layers; and
2) no rigid facing existing during backfill compaction

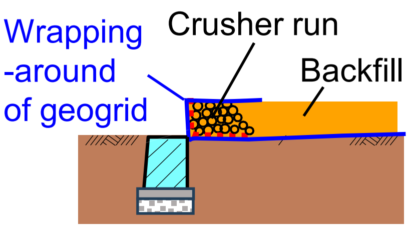
Staged construction: 5)

- Construction of the full-height geogrid-reinforced backfill, before the construction of FHR facing

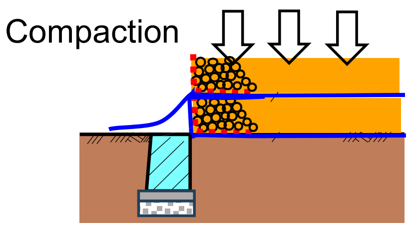
1) Levelling pad & embedded part of FHR facing



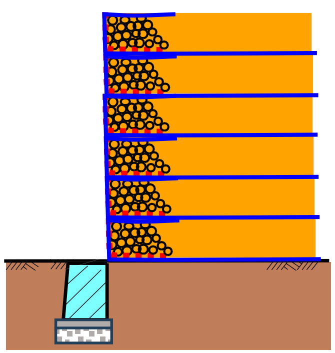
2) Placing the first geogrid layer & a temporary facing unit*



3) Backfilling & compaction of the first soil layer



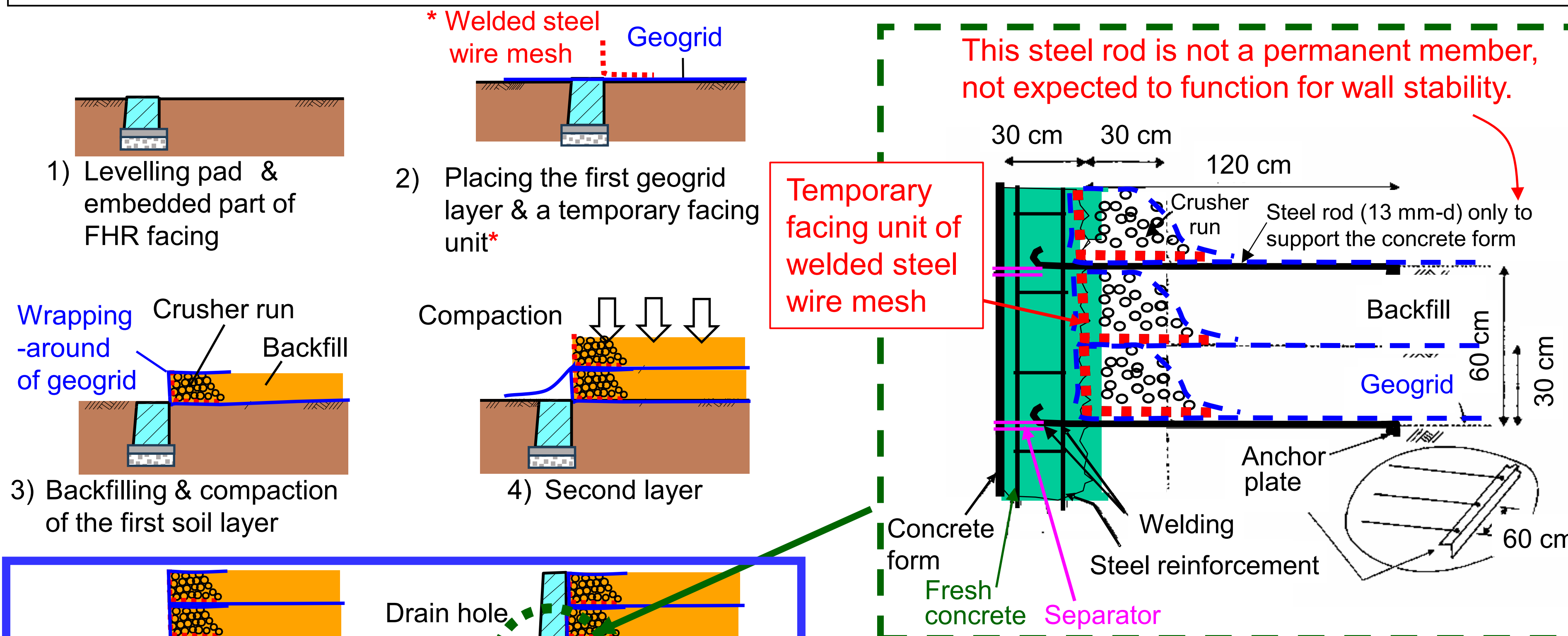
4) Second layer

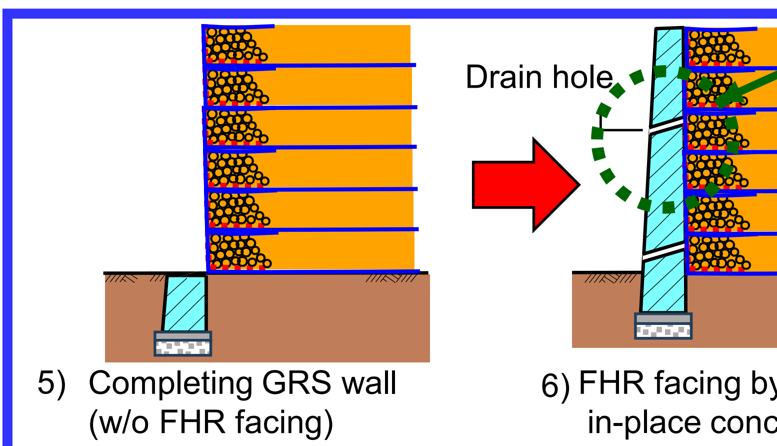


5) Completing GRS wall (w/o FHR facing)

Staged construction from step 5) to step 6):

- After sufficient compression of the backfill & subsoil has taken place, FHR facing is constructed by casting-in-place fresh concrete directly on the geogrid-wrapped-around wall face.

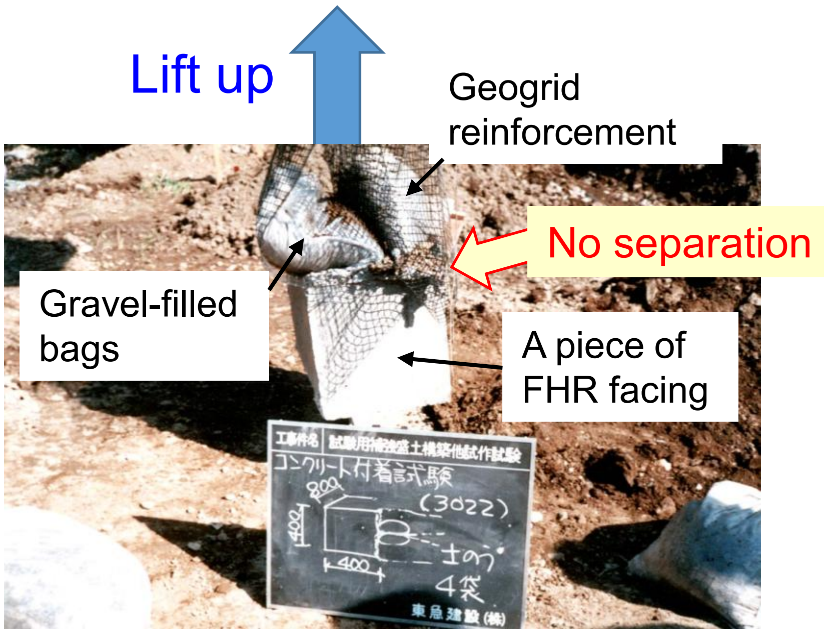




Fresh concrete enters the crusher run zone held in the temporary facing unit of welded steel wire mesh through the aperture of the geogrid ⇒ FHR facing & geogrid layers are firmly connected to each other.

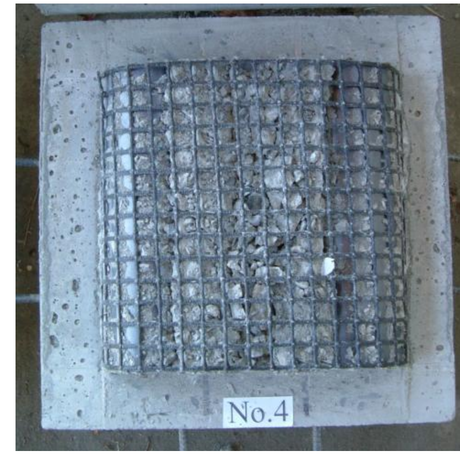
Field & laboratory tests to confirm large separation strength

Field separation test
(when the temporary facing unit is gravel-filled bags)

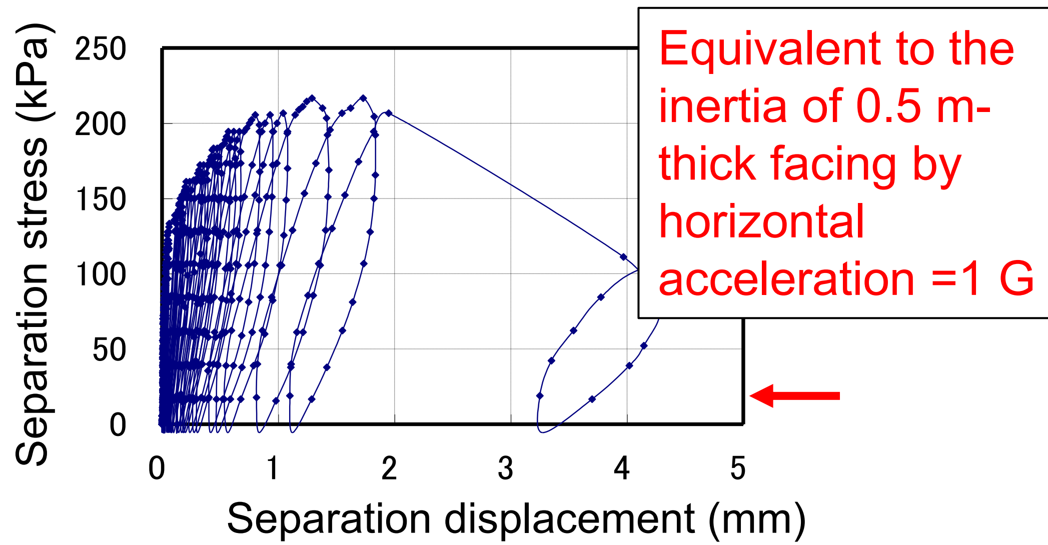


Test specimen (cut out from 40 cm-thick full-scale FHR facing), hung under 1G (= 980 cm/sec^2):

Laboratory separation test

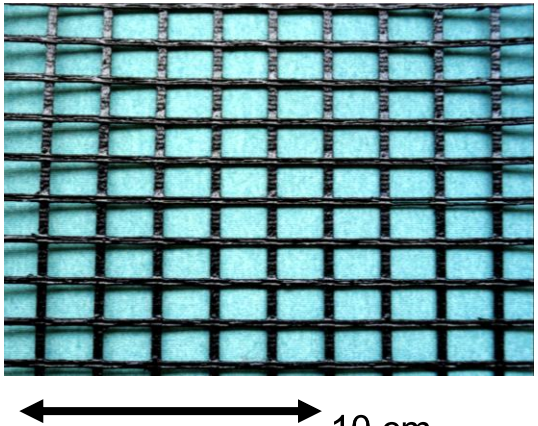


Specimen after separation



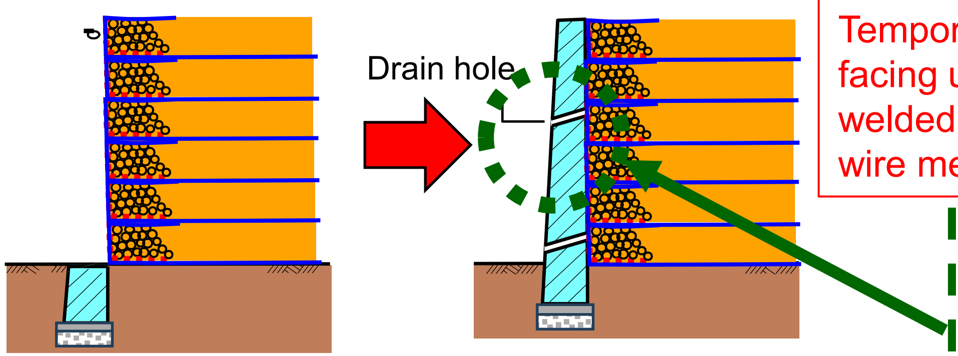
The properties required for the geogrid:

1) Sufficient tensile strength & stiffness with low creep deformation
2) **High anchorage strength in concrete & backfill**
3) **Good adhesiveness with concrete**
4) **High long-term durability against high pH of concrete**



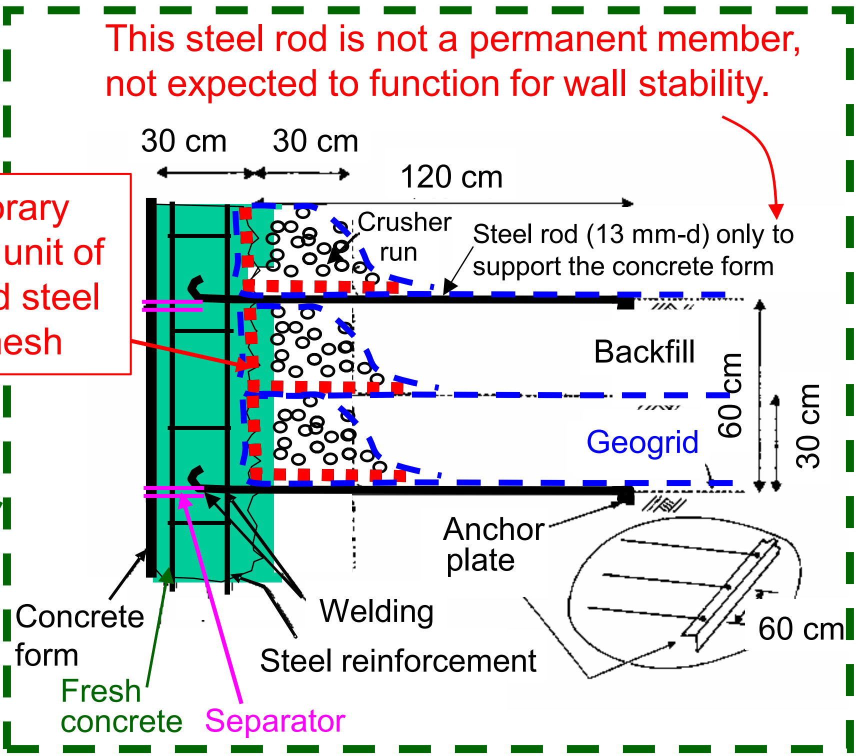
Bi-axial PVA geogrid, satisfying 1) – 4).

2), 3) & 4) are important for RRR GRS structure system, as the geogrid is in direct contact with fresh concrete.



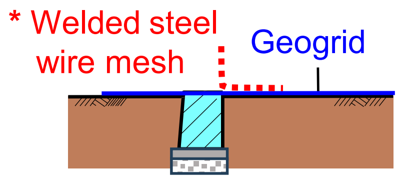
5) Completing GRS wall (w/o FHR facing)

6) FHR facing by casting-in-place concrete

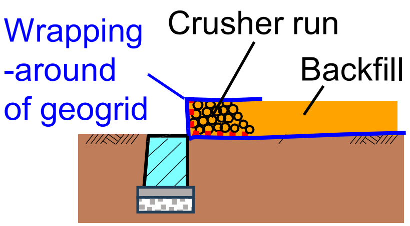


Staged construction: 6)
Completed GRS RW

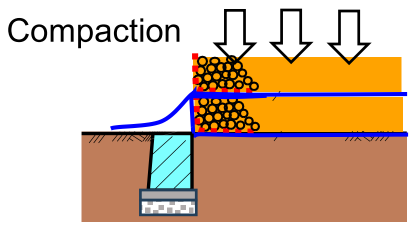
1) Levelling pad & embedded part of FHR facing



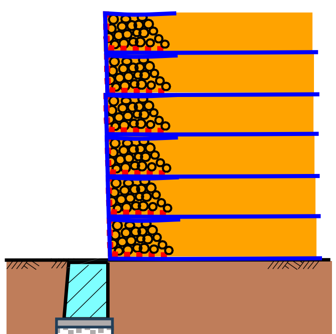
2) Placing the first geogrid layer & a temporary facing unit*



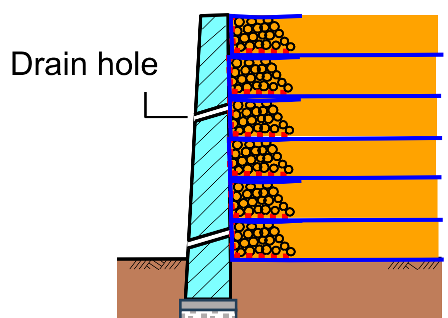
3) Backfilling & compaction of the first soil layer



4) Second layer

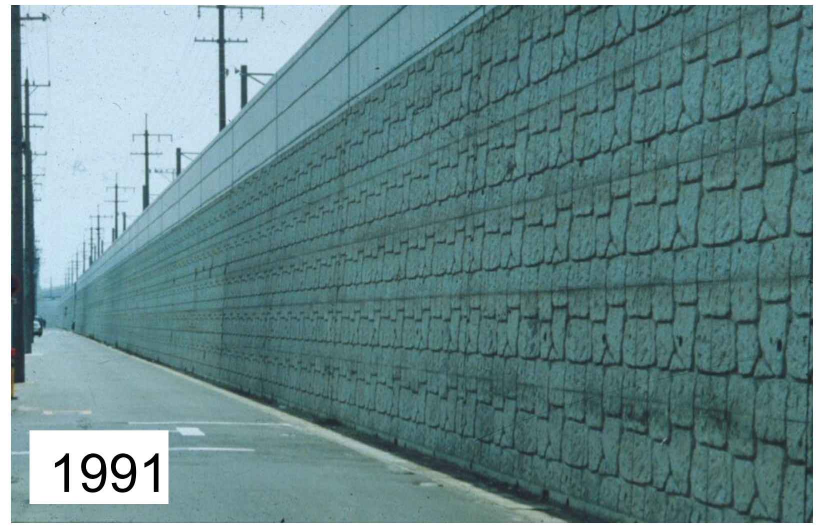


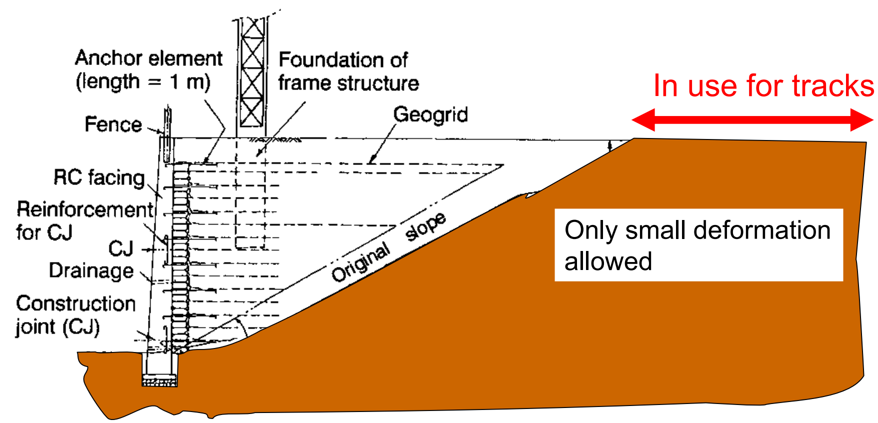
5) Completing GRS wall (w/o FHR facing)



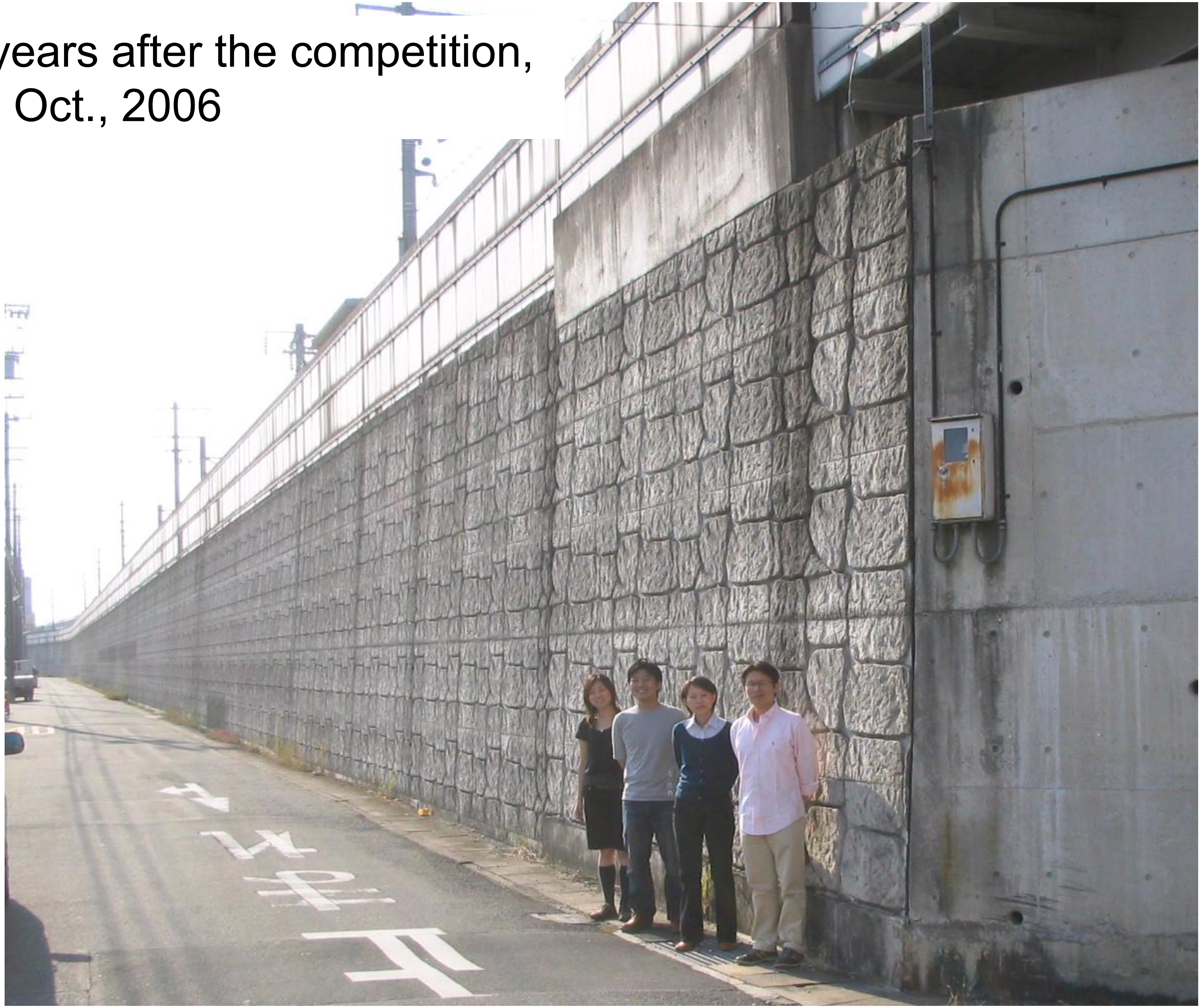
6) FHR facing by casting-in-place concrete

Typical completed GRS RW, depot for HSR (Shinkansen) at Biwajima, Nagoya



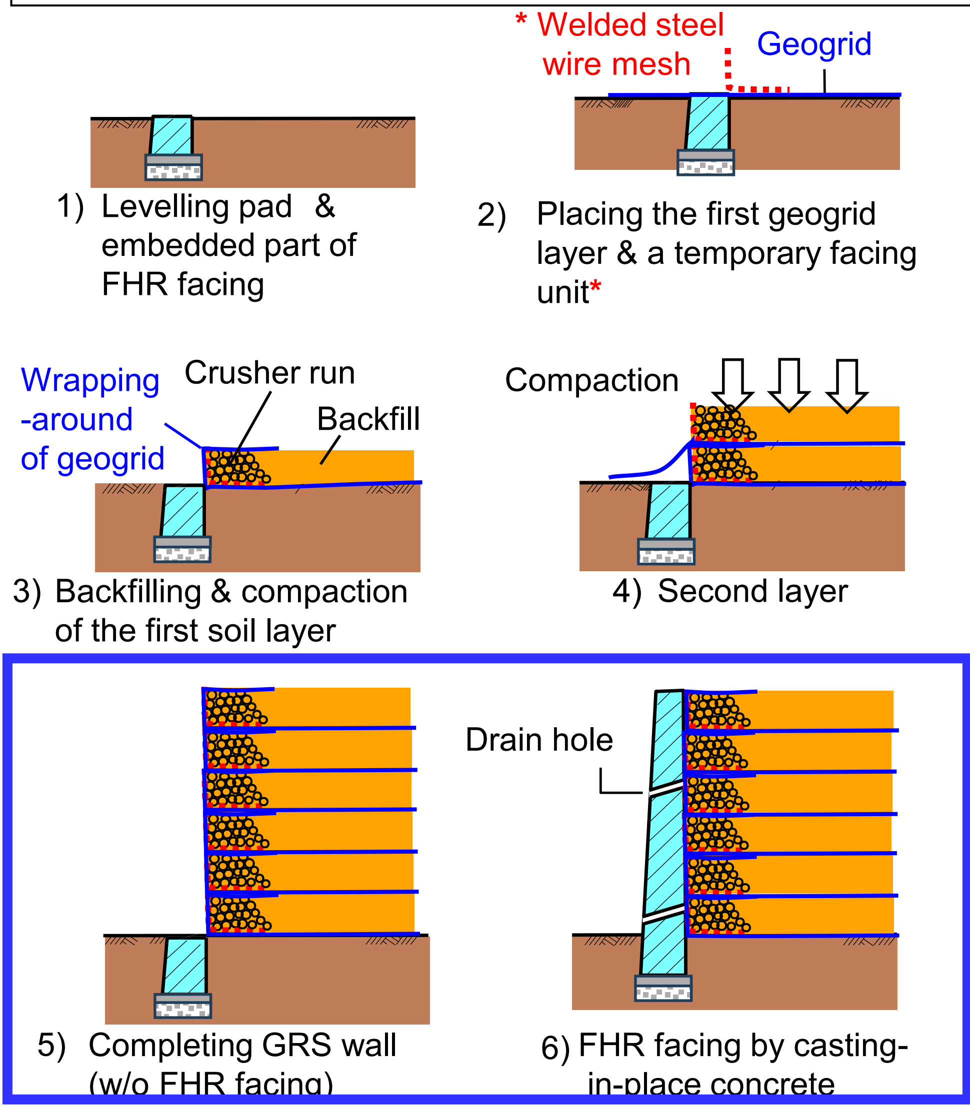


15 years after the competition,
28th Oct., 2006



Advantages of staged construction (steps 5 to 6):

- After sufficient compression of the backfill & subsoil has taken place, FHR facing is constructed by casting-in-place fresh concrete directly on the geogrid-wrapped-around wall face.



1) Very small differential settlements between the FHR facing and the backfill during and after the wall construction.

2) The temporary facing units consisting of welded steel wire mesh and crusher run protect the facing/geogrid connection.

⇒ Essentially no damage to the facing/geogrid connection during long-term service (e.g., even when subjected to severe seismic loads).

⇒ The construction of GRS RW "using compressive backfill" and/or "on a compressive subsoil" becomes possible.

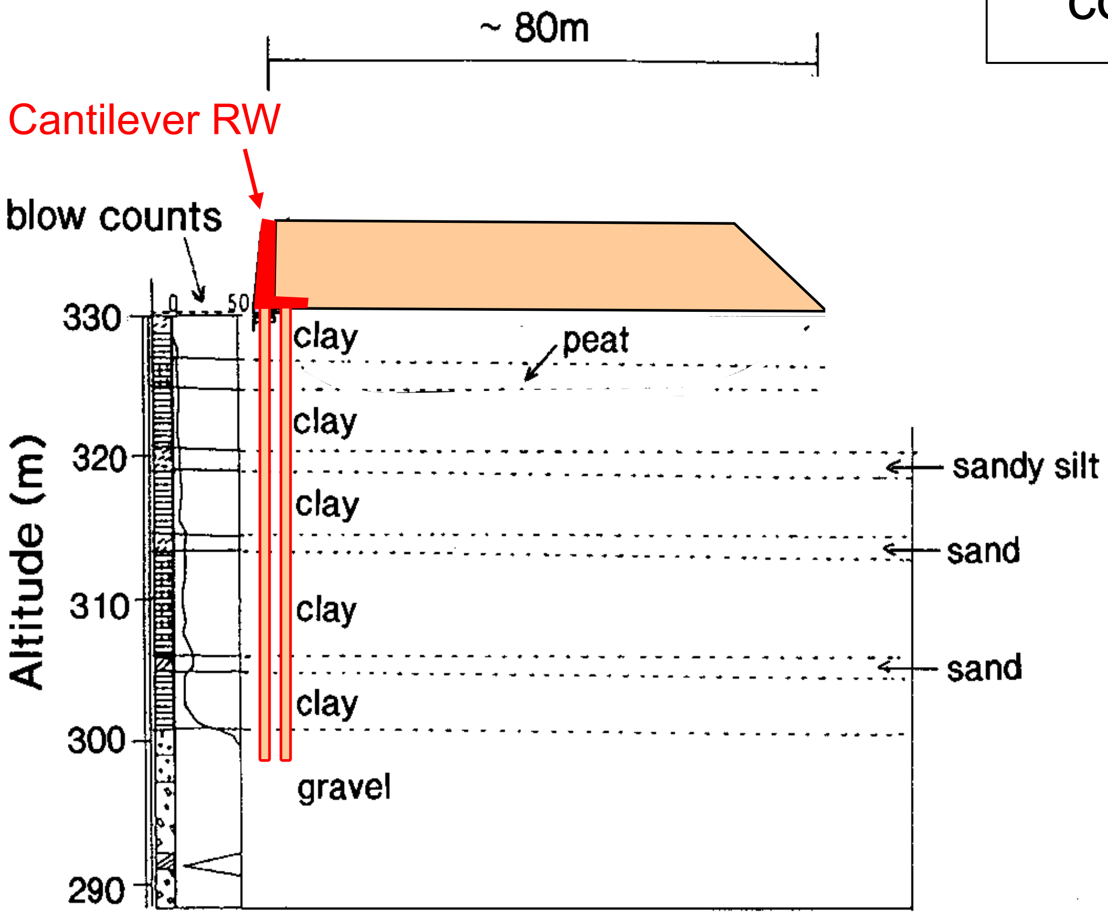
Nagano wall:

- for a depot for HSR (Shinkansen)
- 2.0 m-high & 2 km-long GRS RW
- constructed 1993 - 1994

Very difficult conditions:

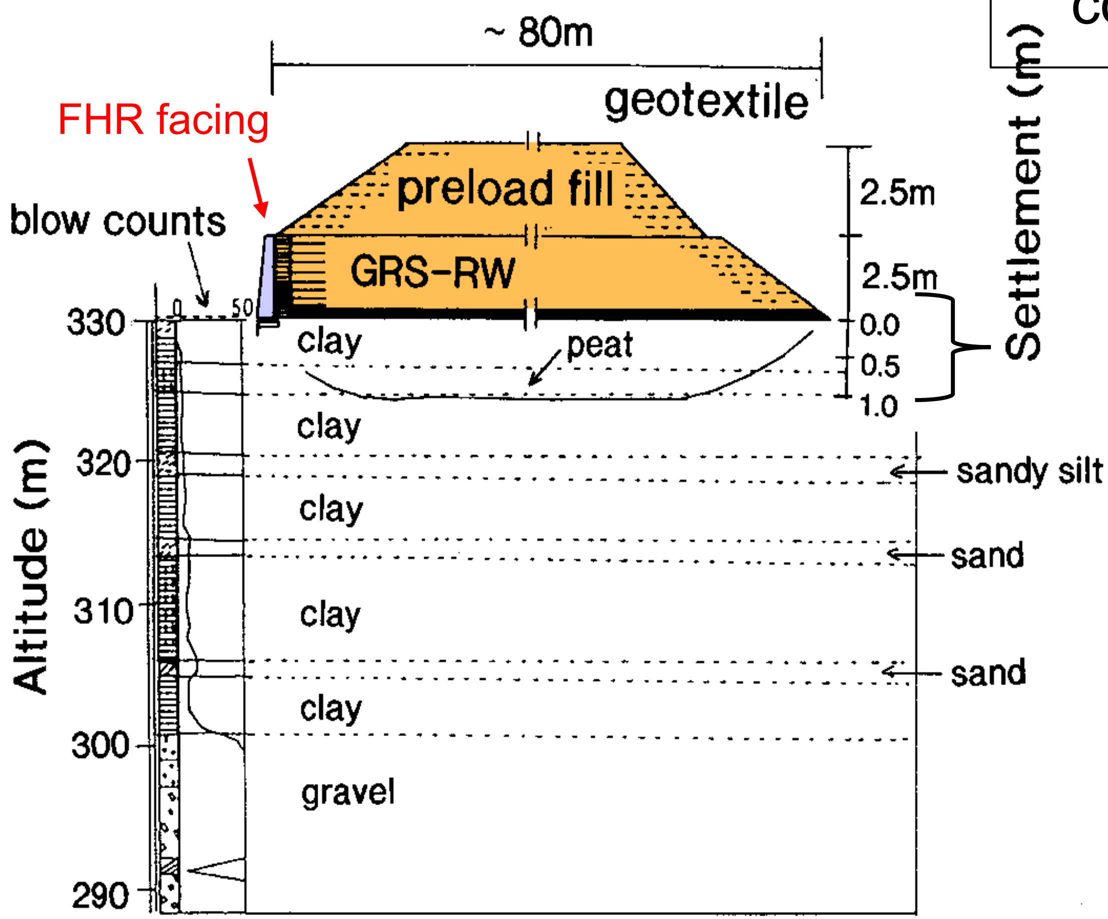
a) soft backfill at a high water content; &

b) a very thick soft clay layer, requiring very long piles for a conventional cantilever RW



Nagano wall:

- for a depot for HSR (Shinkansen)
- 2.0 m-high & 2 km-long GRS RW
- constructed 1993 - 1994



Very difficult conditions:

a) soft backfill at a high water content; &

b) a very thick soft clay layer, requiring very long piles for a conventional cantilever RW

Solved by staged construction of GRS RW:

1) GRS RW w/o FHR facing
2) preload fill
3) settlement (about 1 m)
4) removal of preload fill
5) construction of FHR facing

Preloading

<u>wall height</u>

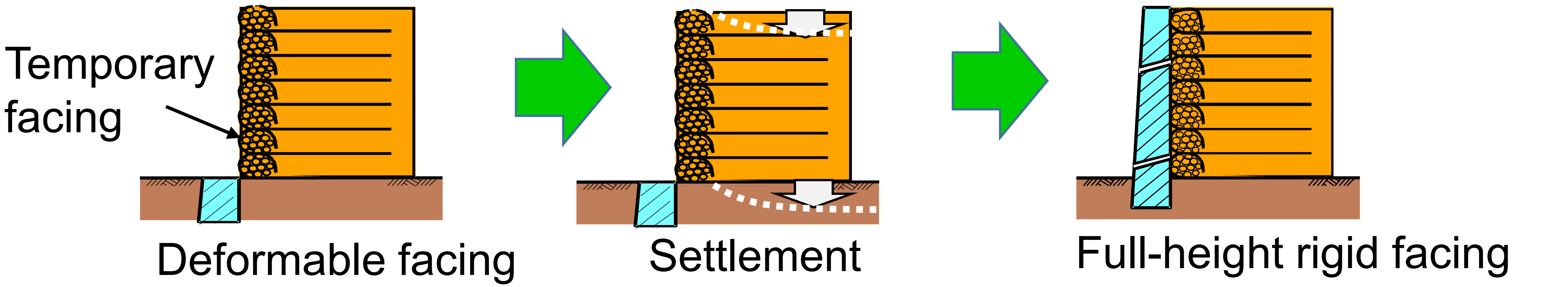
before preloading: 3.0 m

after preloading: 2.0 m

Construction of FHR facing after removing the preload fill.

20 years after construction, 6th July 2014

Required performance of the facing for GRS structures



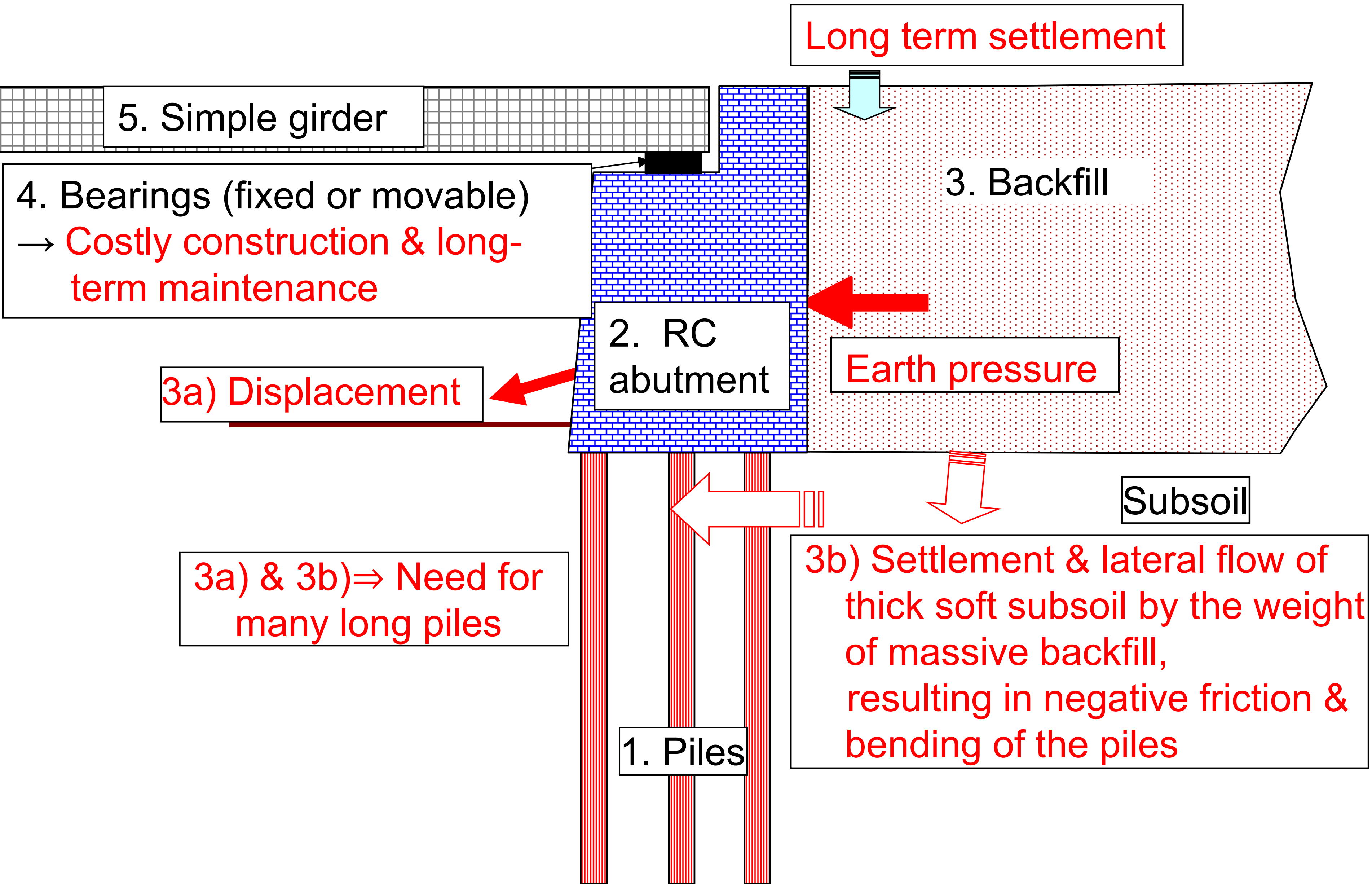
1) During the construction of geogrid-reinforced soil wall (w/o FHR facing), **the temporary facing should be not only strong enough** to keep the temporary wall stable, but also **deformable enough** to accommodate the deformation of backfill & subsoil by the construction of geogrid-reinforced wall.

2) Against static/traffic loads and severe seismic loads and other natural disasters during long-term service, **the FHR facing should be stiff & strong enough** to keeps small the wall deformation ensuring high wall stability.

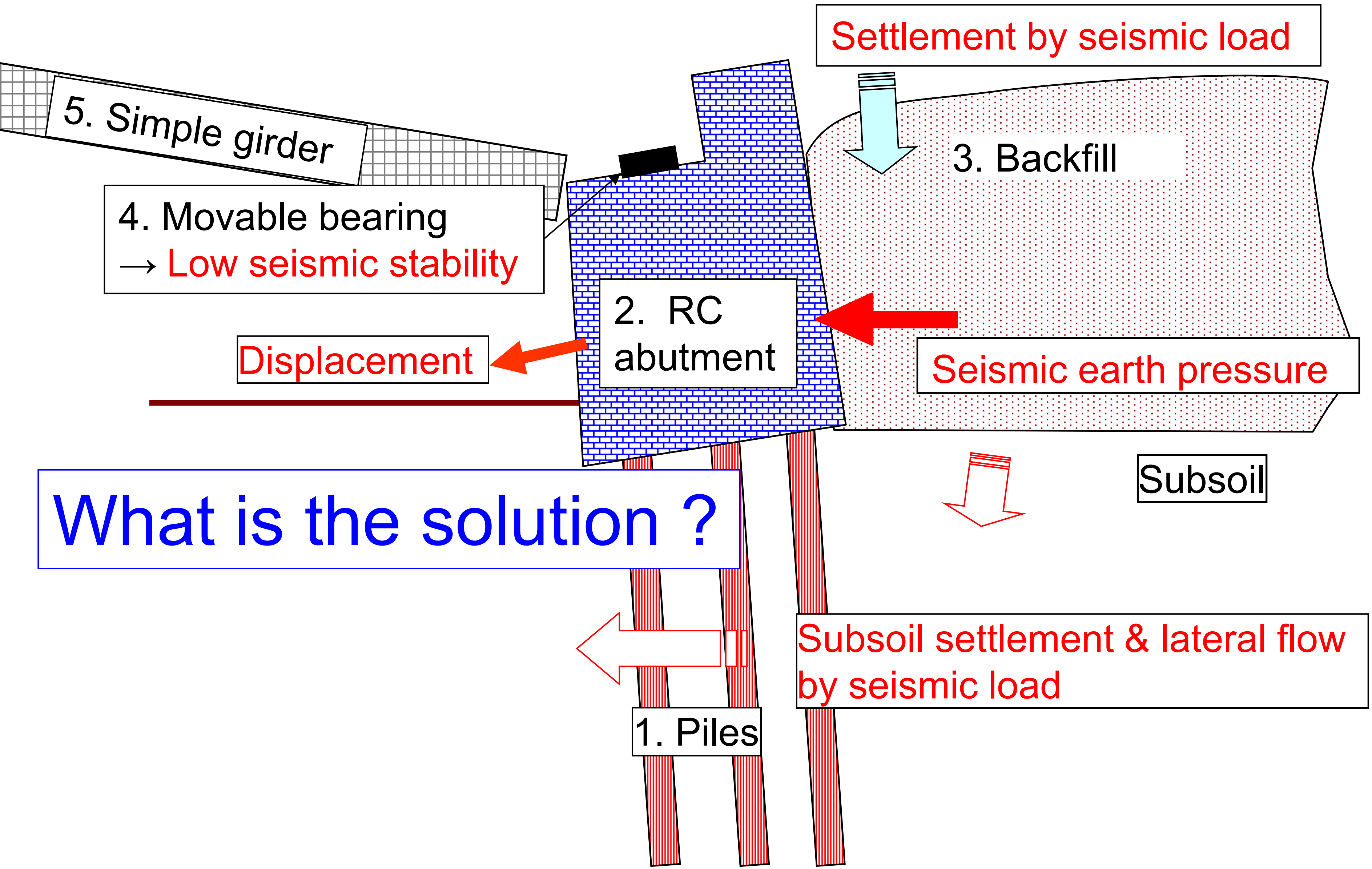
3) These contradicting requirements can be satisfied **by the stage construction in which the FHR facing is constructed after the deformation of backfill & subsoil has completed**.

Contents

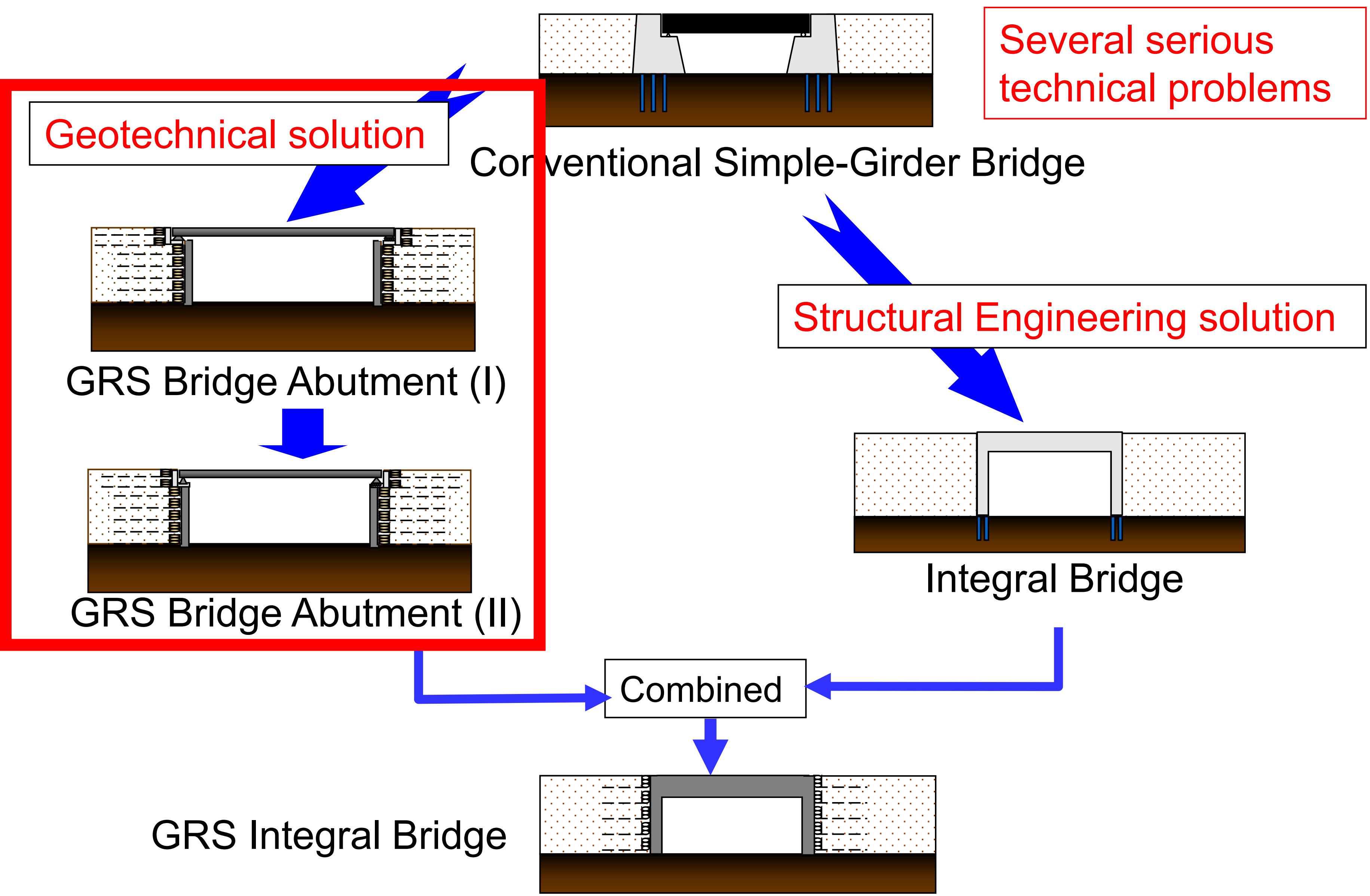
A number of serious problems with conventional simple girder bridge



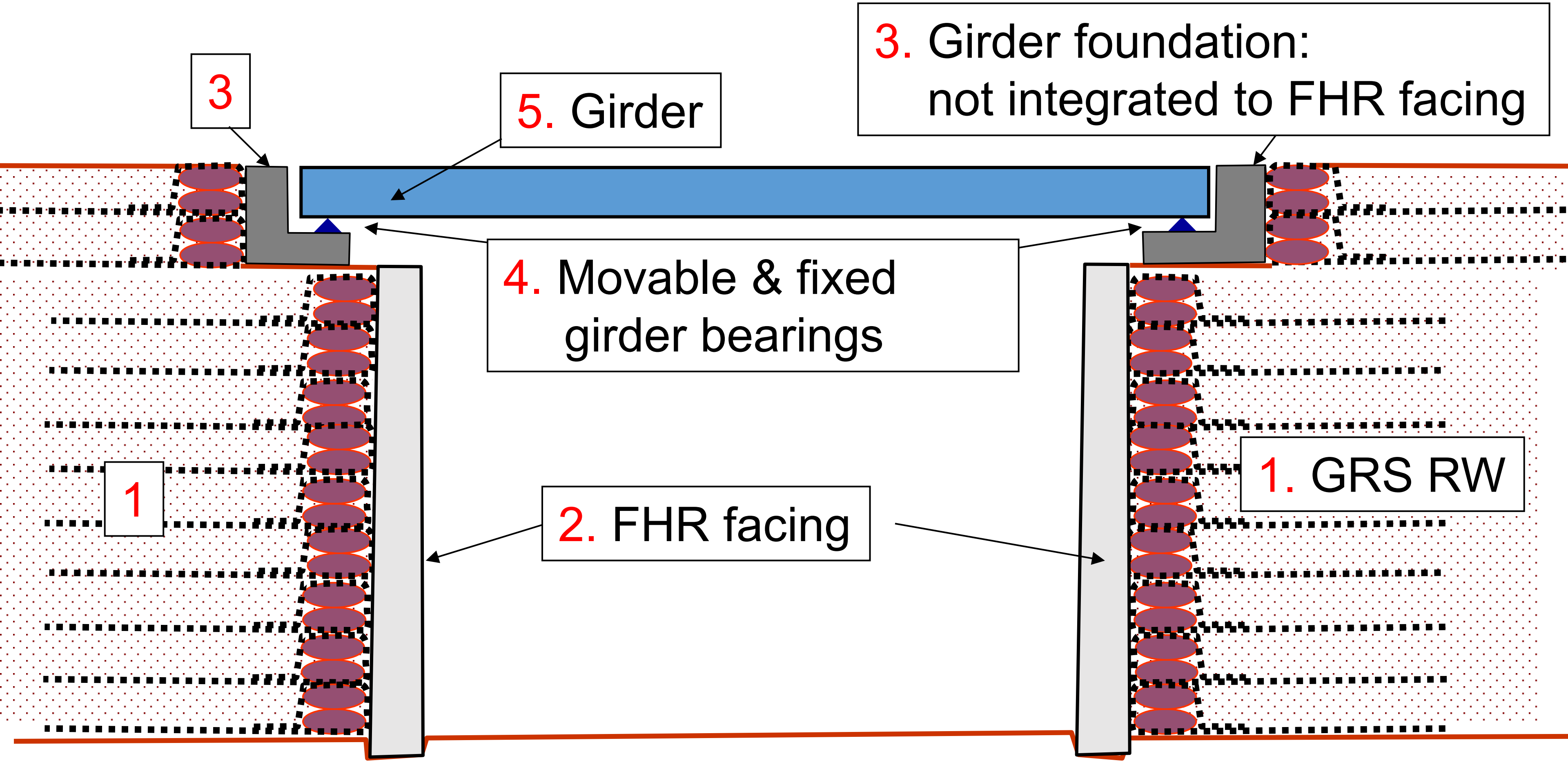
… and problems by seismic loads



Developments from GRS RWs to GRS bridge structures

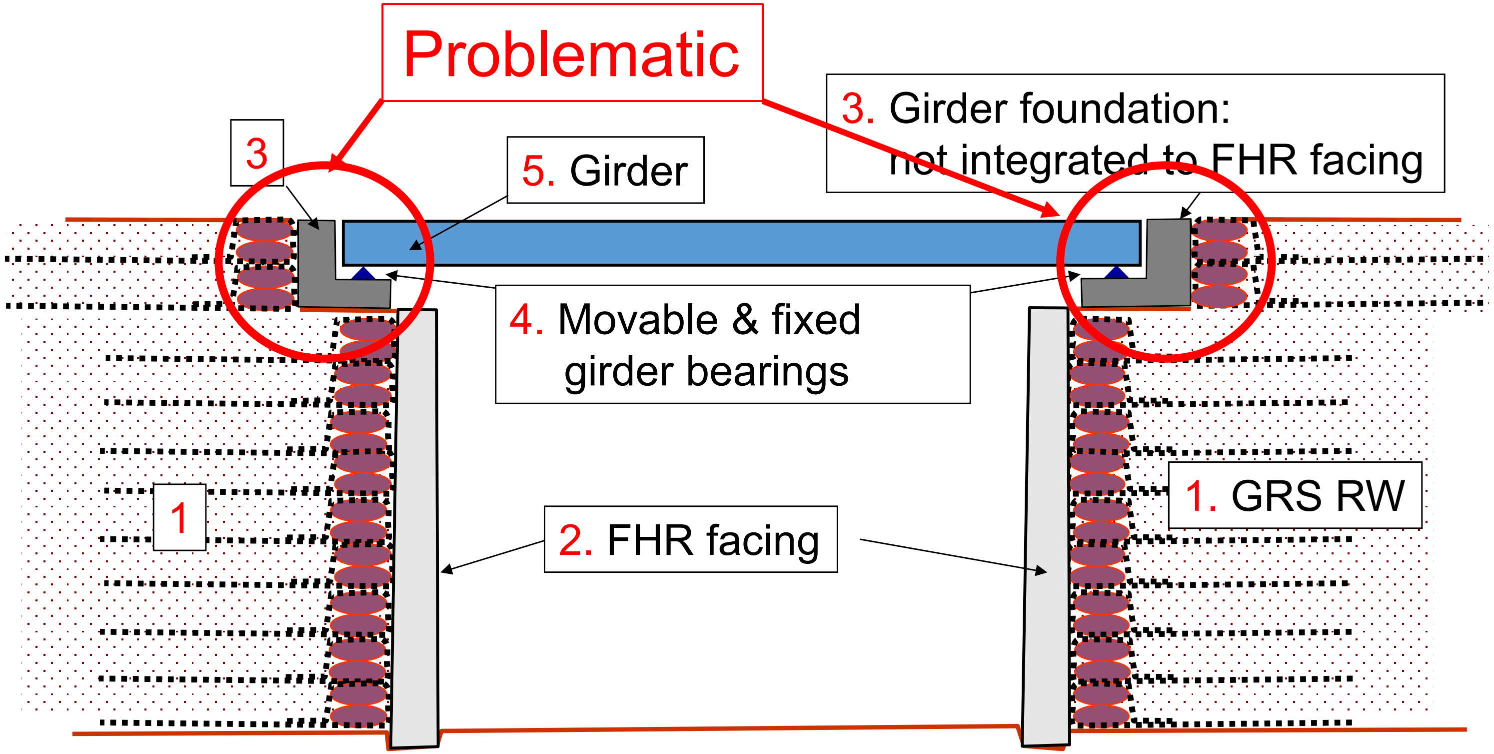


GRS Bridge Abutment – First generation, 1/2



1. No bump right back of the FHR facing ⇒ low maintenance cost
2. Stable approach fills
3. Highly cost-effective

GRS Bridge Abutment – First generation, 2/2



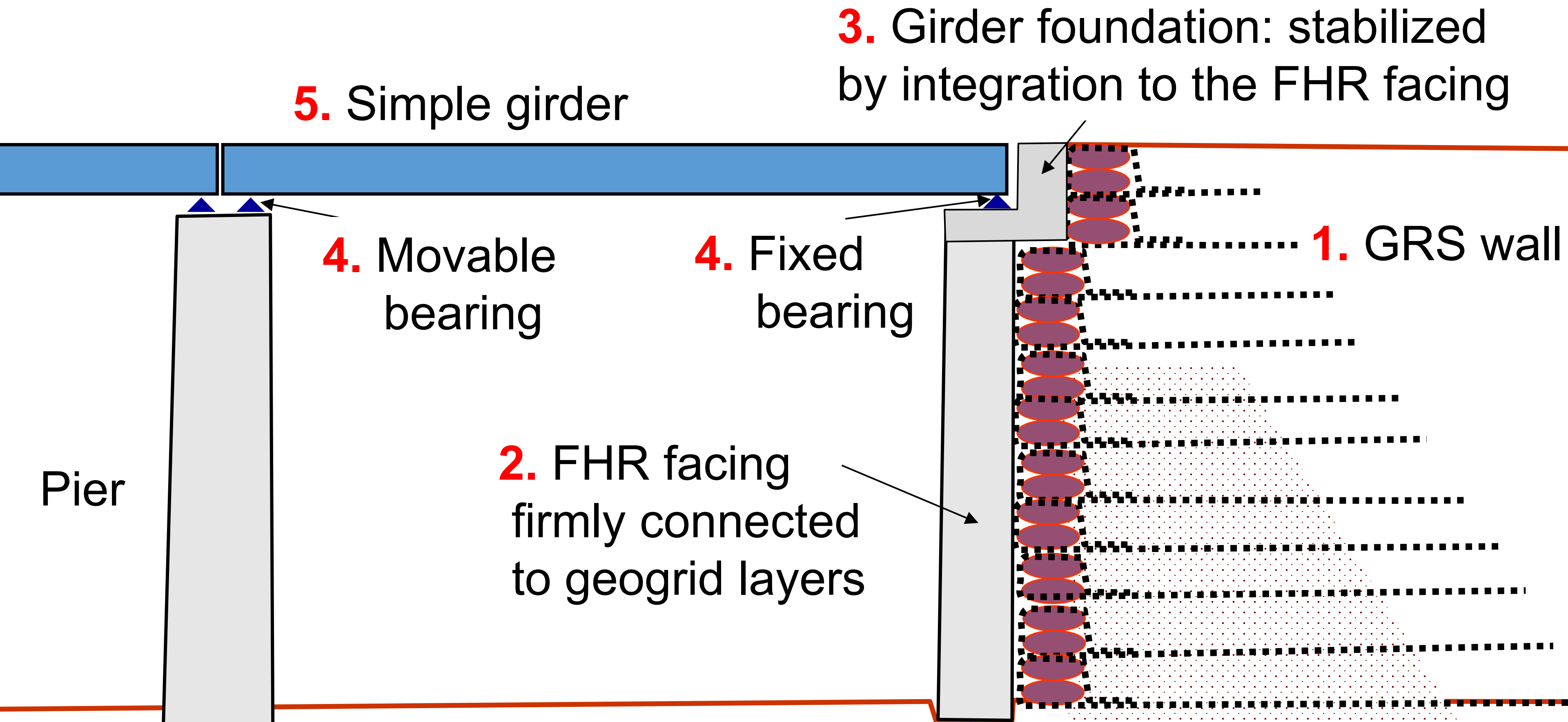
However, two remaining problems:

When the girder becomes long and heavy,

1) the girder foundation where the fixed bearing is arranged becomes unstable by large seismic inertia load acting at the girder; and
2) the settlement of the girder foundation due to the compression of the underlying backfill may become unacceptable.

⇒ Development of GRS Bridge Abutment of second generation

GRS Bridge Abutment – Second generation



Much more stable & cost-effective than the conventional type bridge abutment.

Besides, GRS Bridge Abutment is statically determinate due to the use of a bearing. So, the internal forces in the girder & FHR facing are not sensitive to a limited amount of displacement of the facing.

⇒ The design of the girder & FHR facing is not sophisticated.

GRS Bridge Abutment, completed 2020
Timoshenko No. 1,
Hokuriku Shinkansen

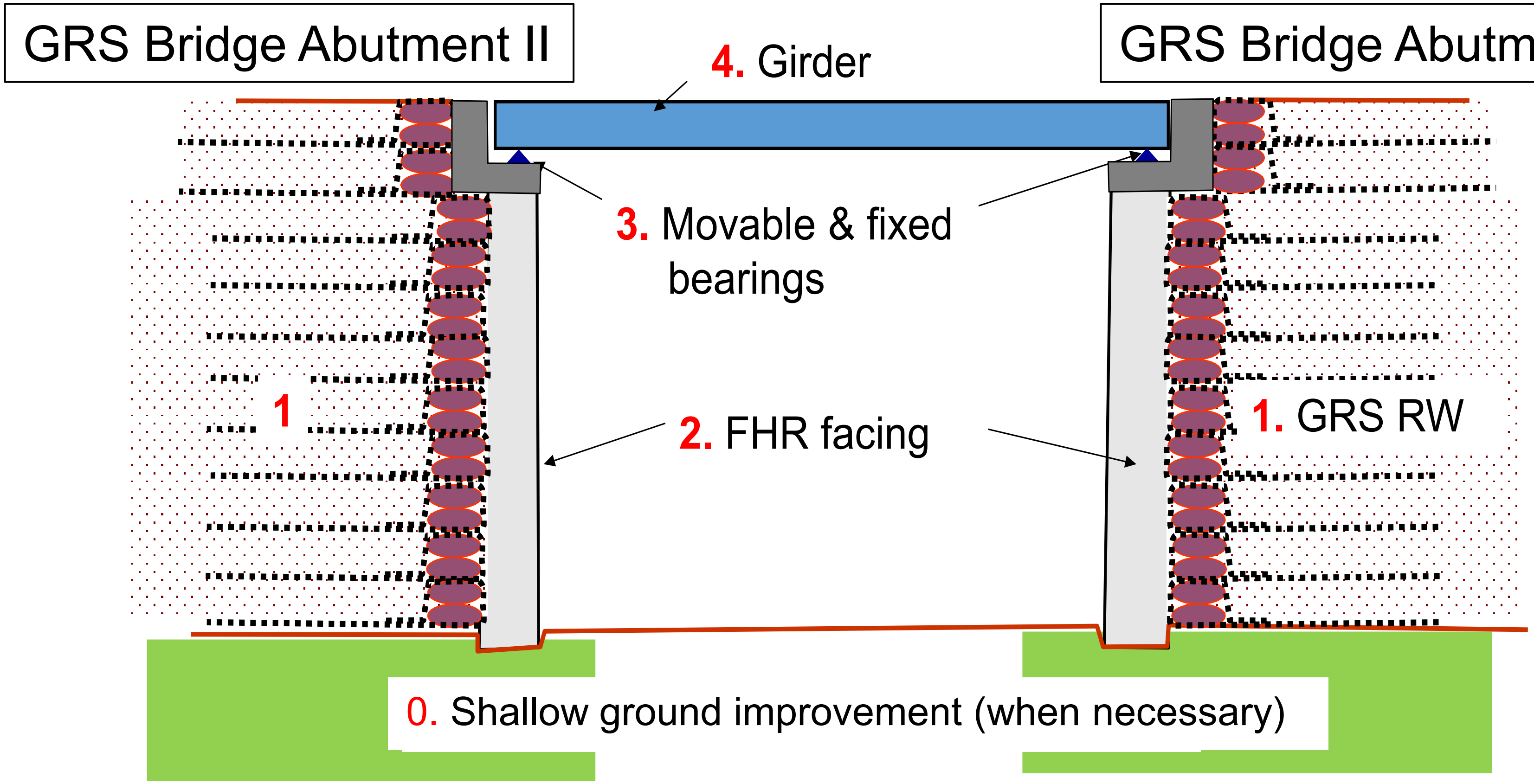
By the courtesy of Mr. Yonezawa, T., JRTT

GRS Bridge Abutment, completed 2020
Shimo-shinjo No. 1, Hokuriku Shinkansen

By the courtesy of JRTT

GRS Bridge Abutments (2nd generation):
- a simple girder is supported by bearings arranged at the crest of a pair of FHR facings

Much better performance & much higher cost-effectiveness than the conventional simple girder bridge, so relevant in many cases.



Simple girder supported by a pair of GRS Bridge Abutments
Kyushu Shinkansen, Nishi-Nihon Route, 28 October, 2022

GRS Bridge Abutment

GRS Bridge Abutment

Summary of GRS Bridge Abutment – Second generation

First GRS Bridge Abutment,
at Takada for Kyushu Shinkansen

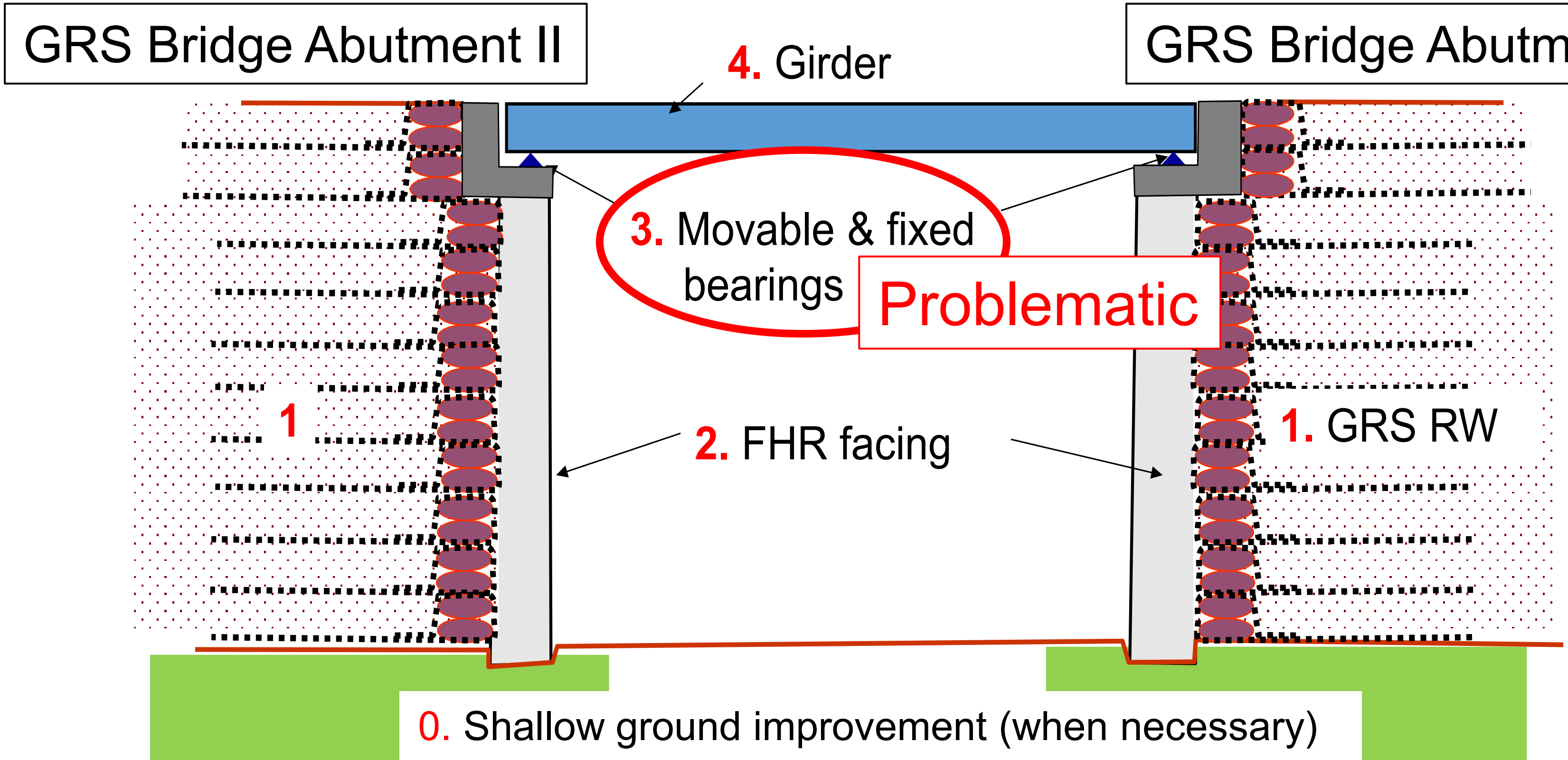
GRS Bridge Abutment at Mantaro
for Hokkaido Shinkansen

- First one at Takada in 2003
- As of 2025, in total about 200, including:
  - 63 for Hokkaido High Speed Railway (Shinkansen);
  - 79 for Kyushu HSR; and
  - 49 for Hokuriku HSR

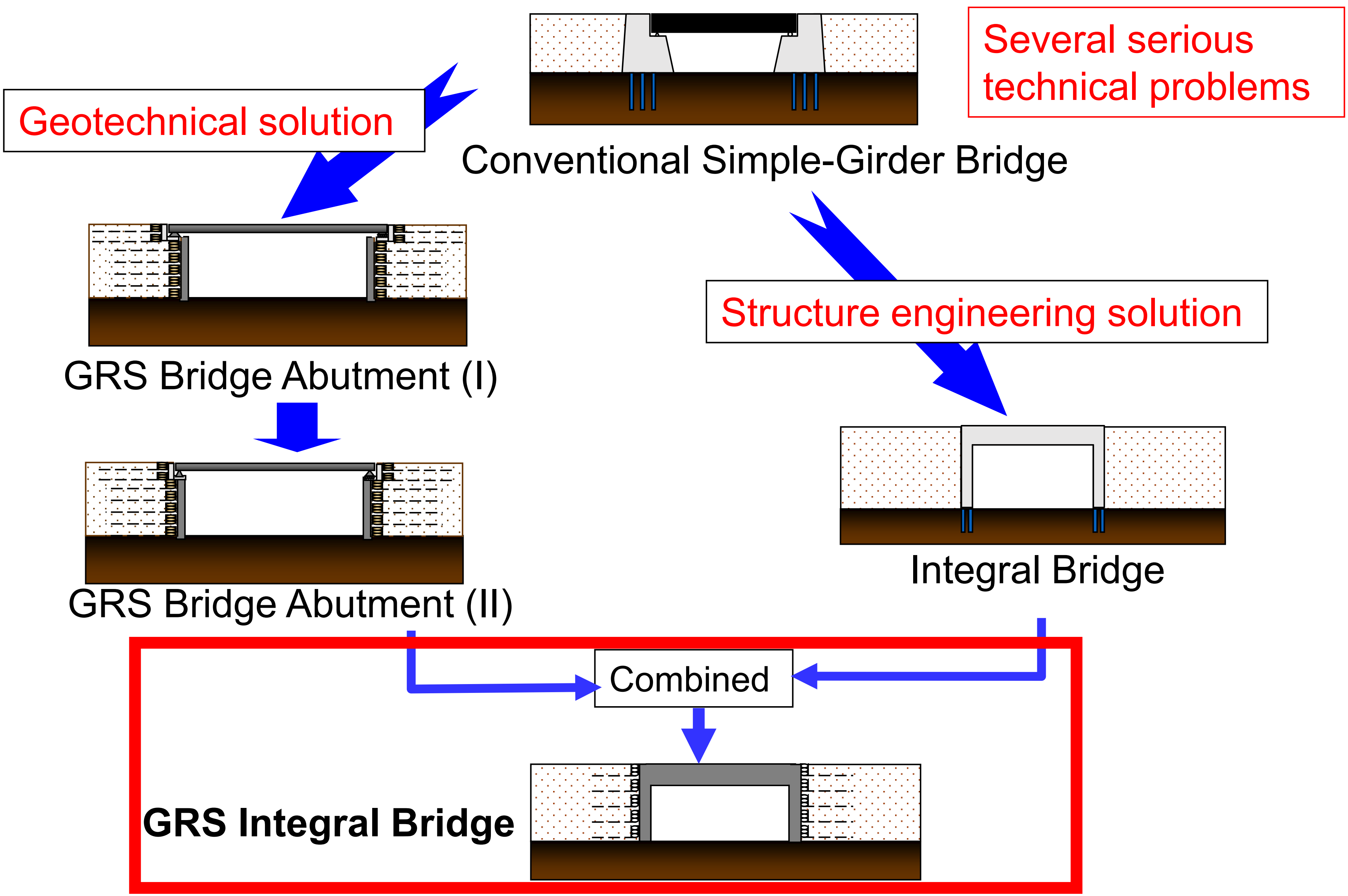
GRS Bridge Abutments (2nd generation):
- a simple girder is supported by bearings arranged at the crest of FHR facings

Still two unsolved problems:
1) high cost for construction & maintenance of the bearings; and
2) low seismic stability of the girder at the movable bearing.

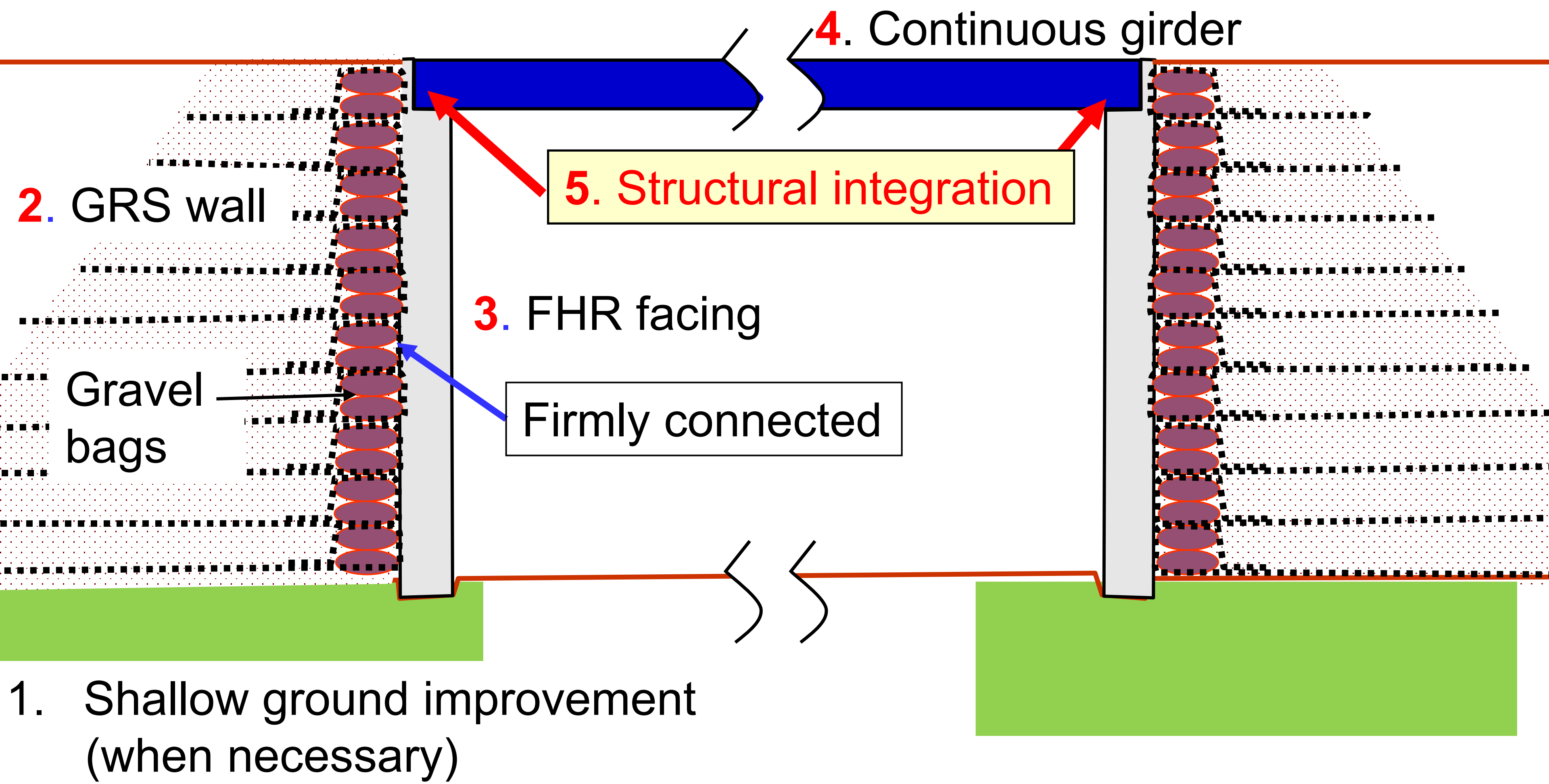
⇒Development of GRS Integral Bridge to alleviate these problems



Developments from GRS RWs to GRS bridge structures



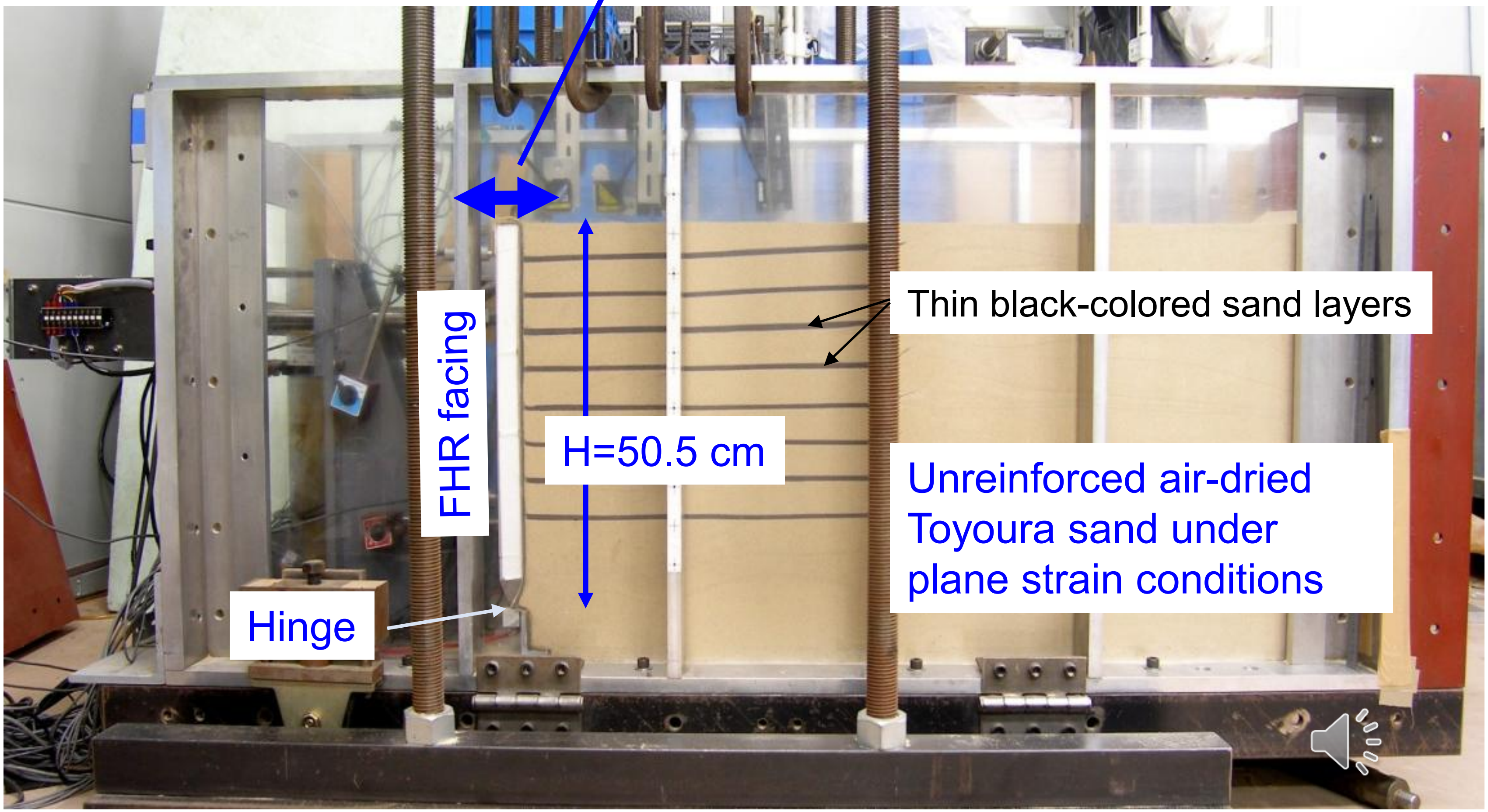
GRS Integral Bridge



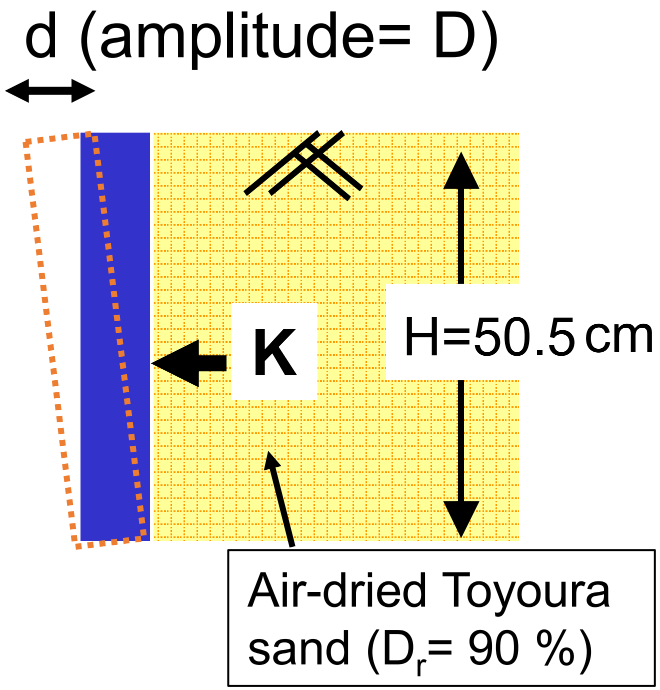
⇒ Static and dynamic model tests to evaluate the performance of GRS Integral Bridge

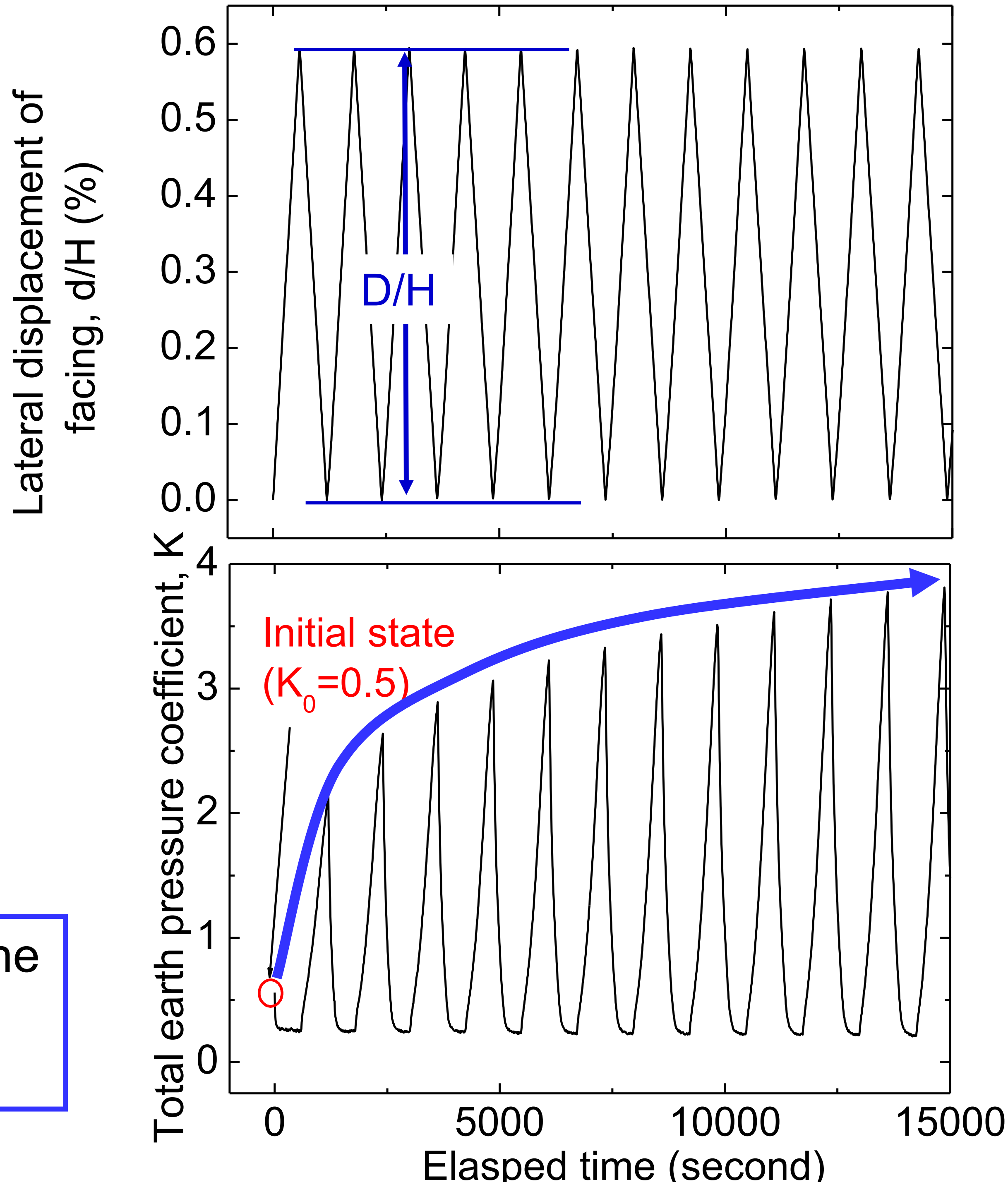
Cyclic lateral loading model test in 1g (considered model scale: 1/10)

Simulated static small cyclic displacements at the top of facing due to seasonal thermal expansion & contraction of girder

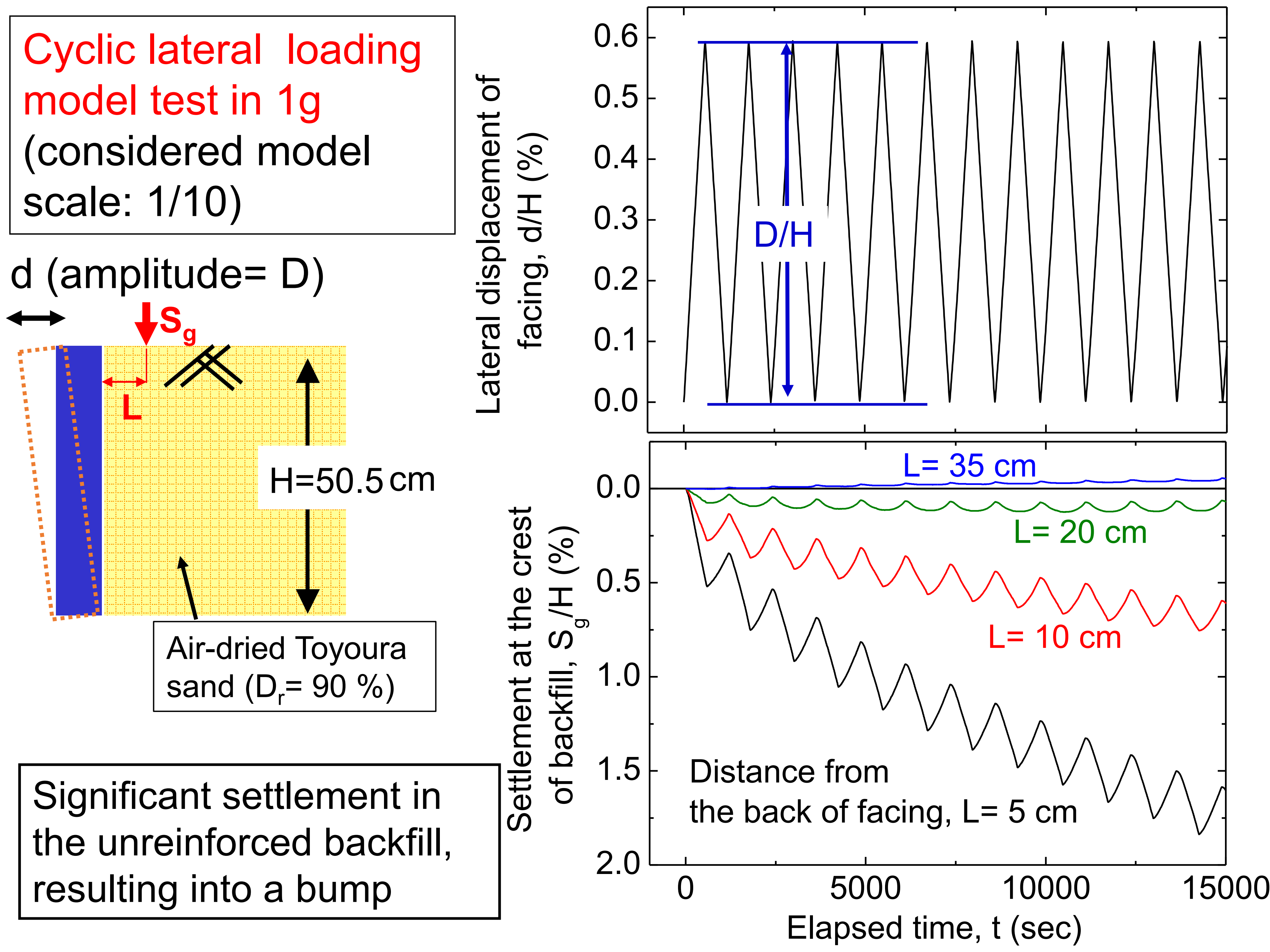


Cyclic lateral loading model test in 1g (considered model scale: 1/10)



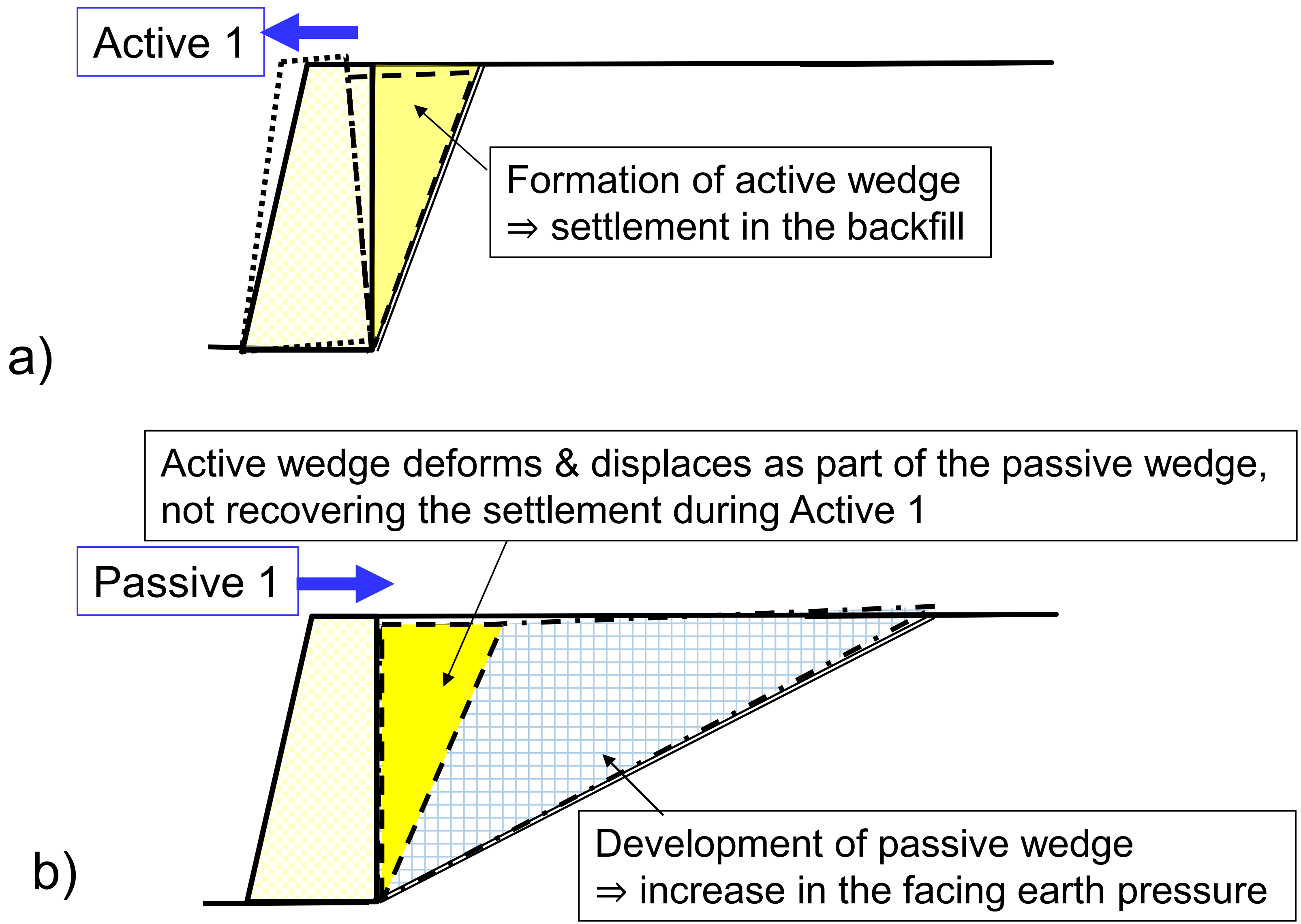


Significant increase in the earth pressure in the unreinforced backfill

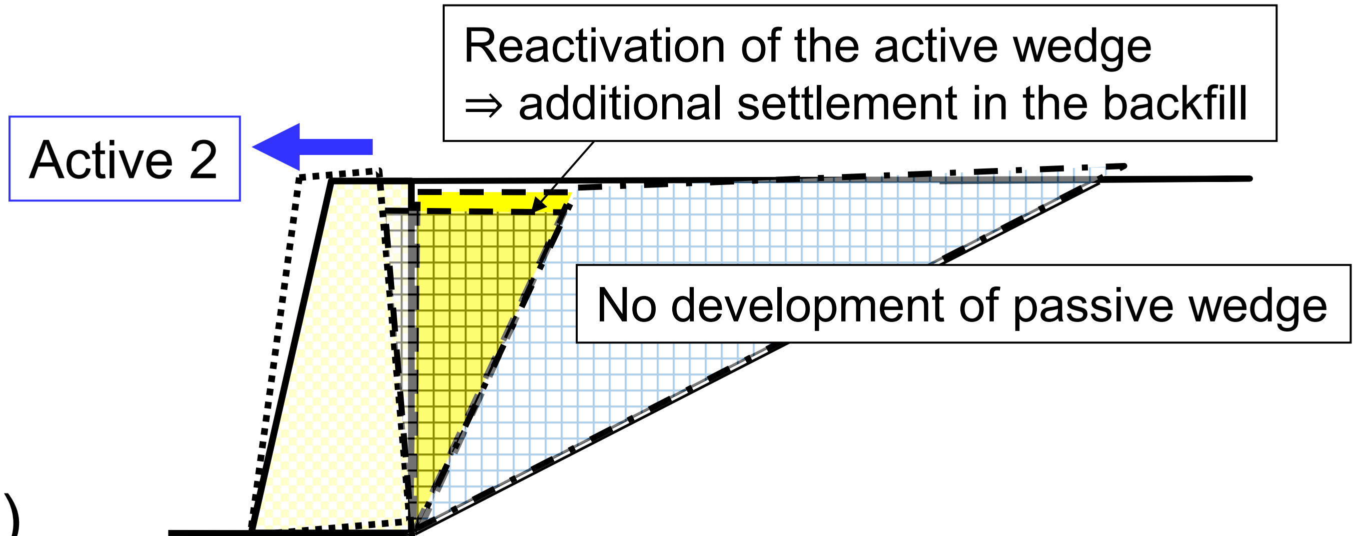


Cyclic lateral loading model test in 1g
(considered model scale: 1/10)
d (amplitude= D)
S_g
L
H=50.5 cm
Air-dried Toyoura sand (D_r= 90 %)
Significant settlement in the unreinforced backfill, resulting into a bump
Lateral displacement of facing, d/H (%)
D/H
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Settlement at the crest of backfill, S_g/H (%)
L= 35 cm
L= 20 cm
L= 10 cm
Distance from the back of facing, L= 5 cm
0.0
0.5
1.0
1.5
2.0
0
5000
10000
15000
Elapsed time, t (sec)

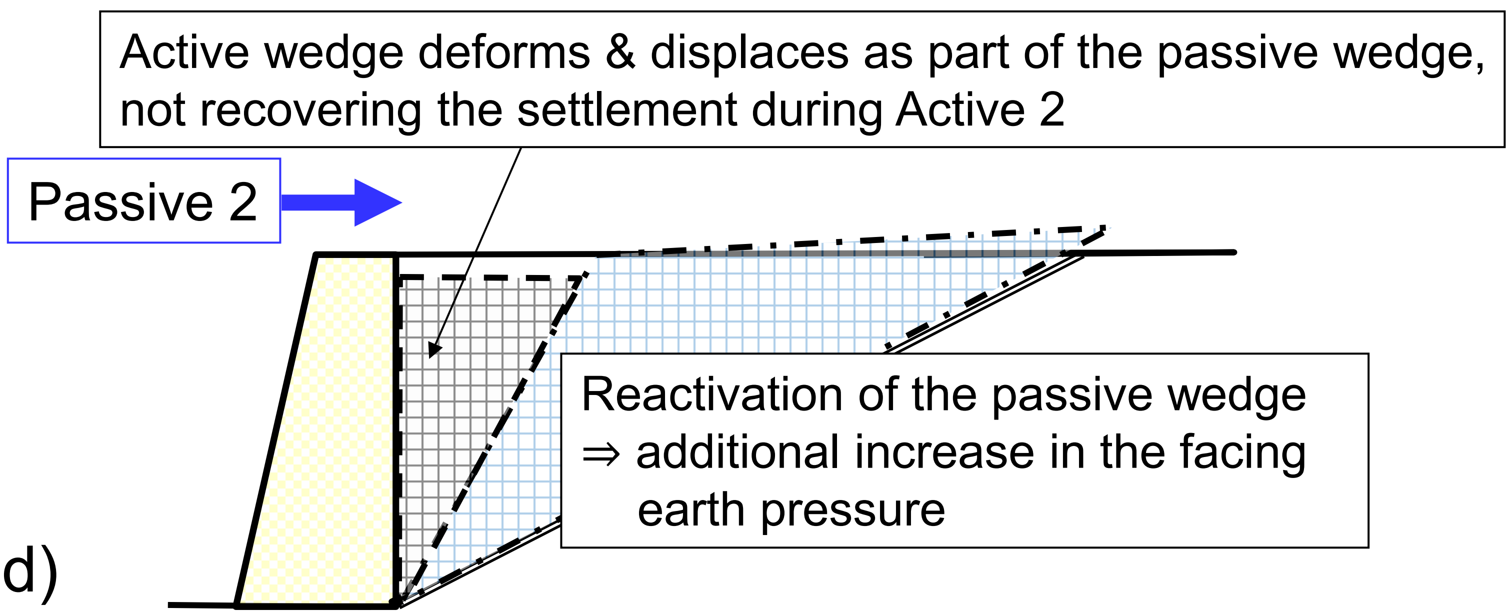
Dual ratchet mechanism, continuously developing both: 1) backfill settlement; and 2) earth pressure- 1



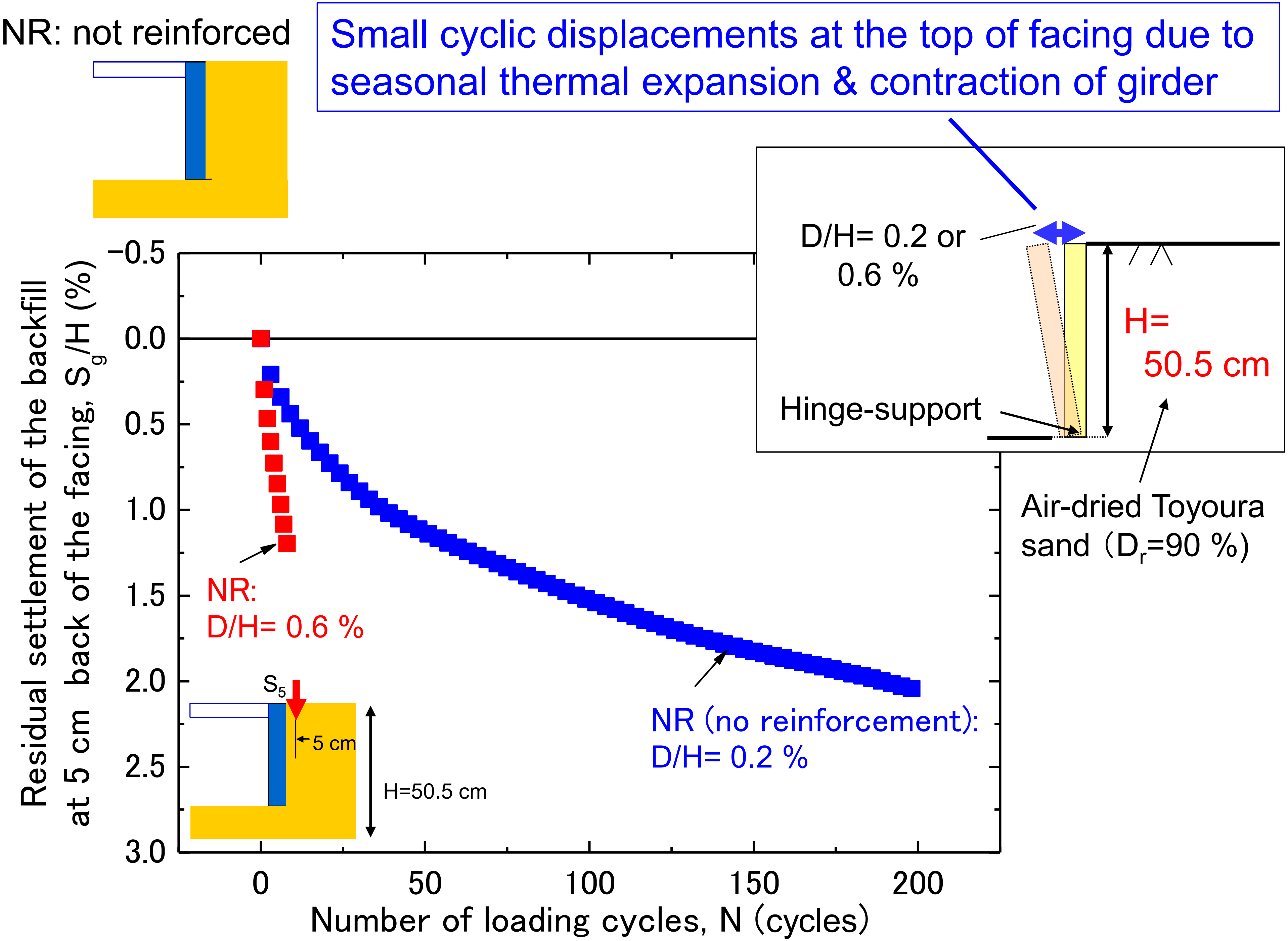
Dual ratchet mechanism, continuously developing both: 1) backfill settlement; and 2) earth pressure- 2



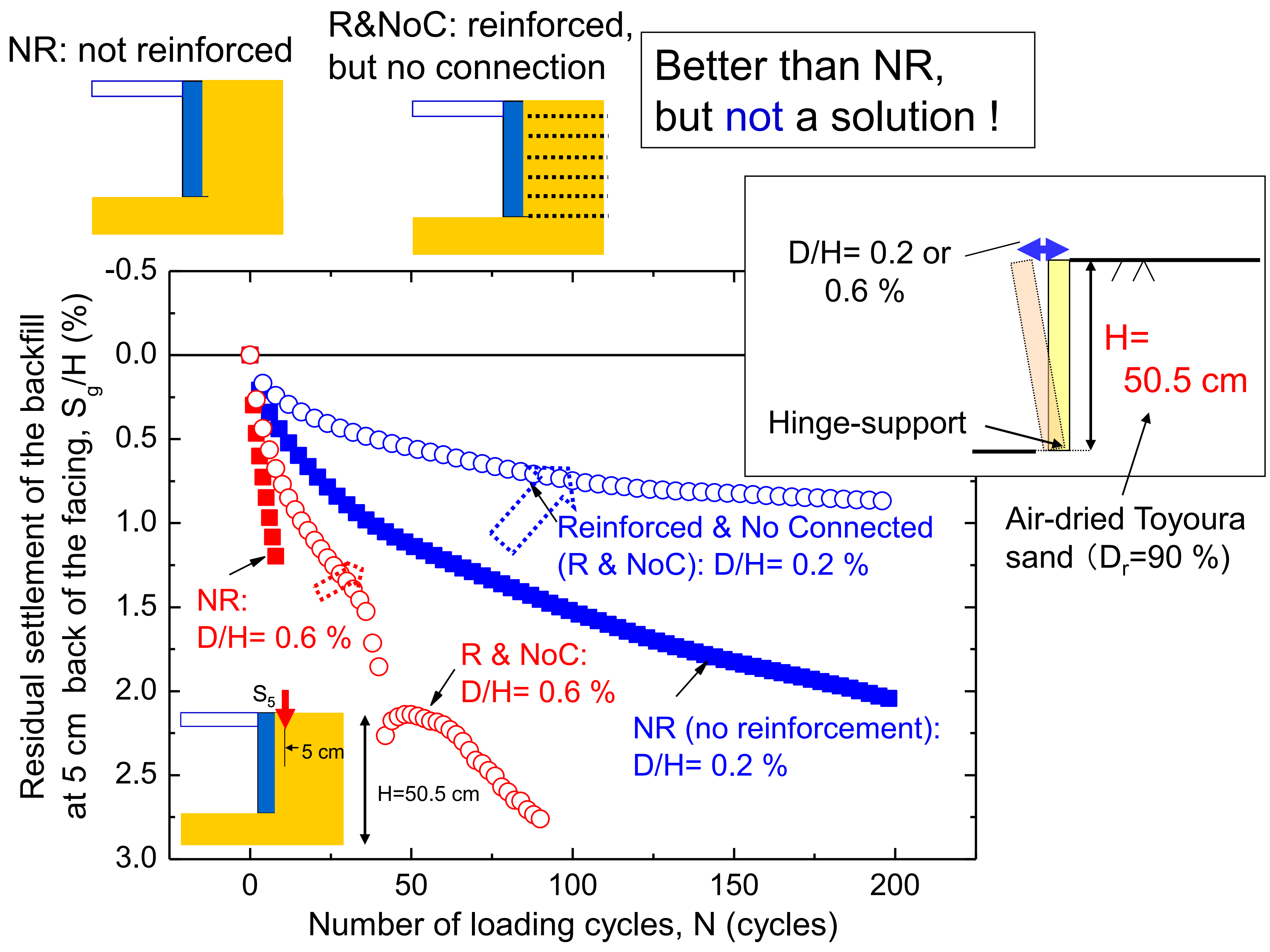
c)



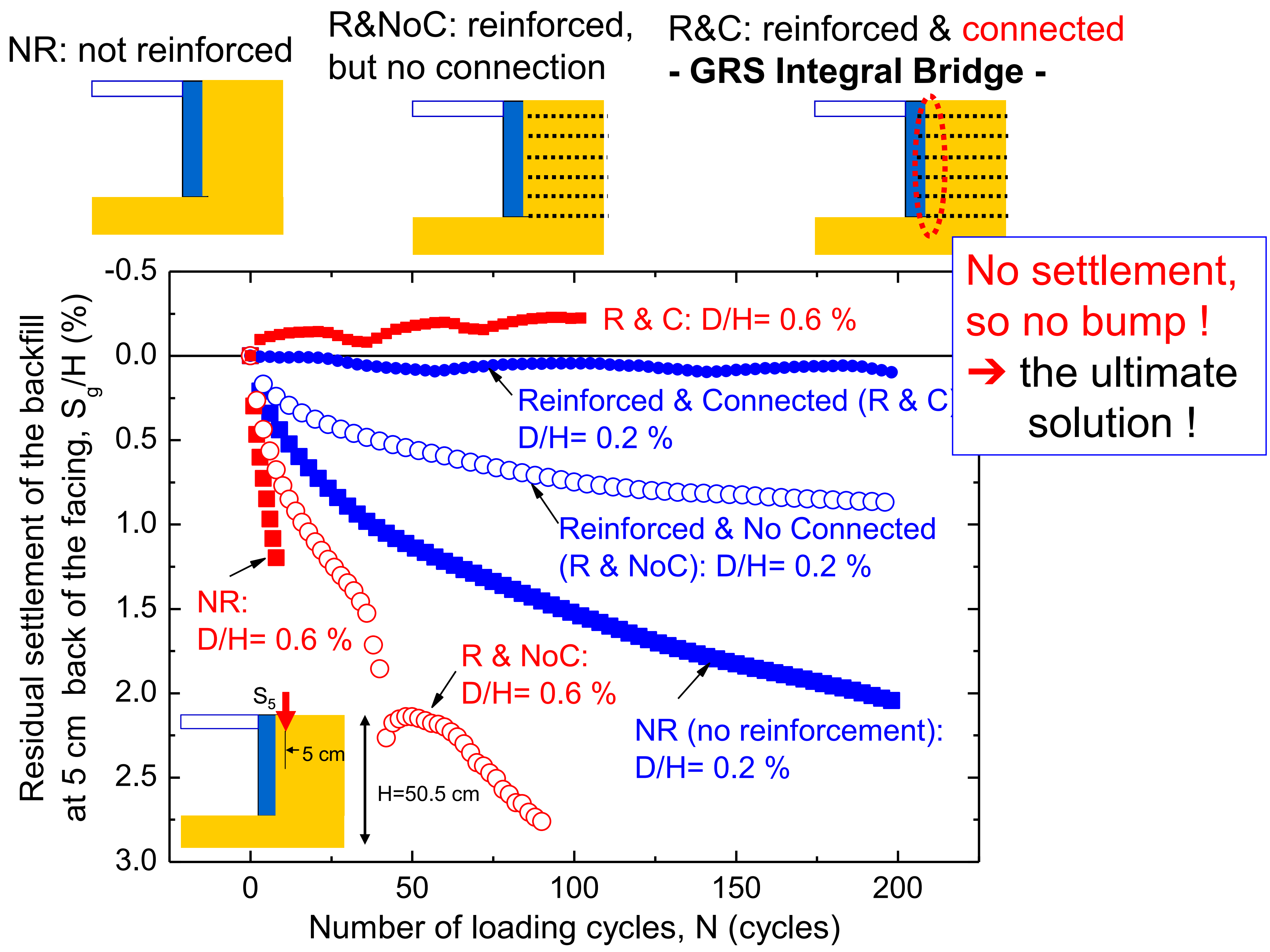
d)



NR: not reinforced
Small cyclic displacements at the top of facing due to seasonal thermal expansion & contraction of girder
D/H= 0.2 or 0.6 %
H= 50.5 cm
Hinge-support
Air-dried Toyoura sand (D_r=90 %)
Residual settlement of the backfill at 5 cm back of the facing, S_g/H (%)
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
NR: D/H= 0.6 %
NR (no reinforcement): D/H= 0.2 %
S_5
5 cm
H=50.5 cm
0
50
100
150
200
Number of loading cycles, N (cycles)



NR: not reinforced
R&NoC: reinforced, but no connection
Better than NR, but not a solution !
D/H= 0.2 or 0.6 %
H= 50.5 cm
Hinge-support
Air-dried Toyoura sand（D_r=90 %）
Reinforced & No Connected (R & NoC): D/H= 0.2 %
NR: D/H= 0.6 %
R & NoC: D/H= 0.6 %
NR (no reinforcement): D/H= 0.2 %
S_5
5 cm
H=50.5 cm
Residual settlement of the backfill at 5 cm back of the facing, S_g/H (%)
Number of loading cycles, N (cycles)
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200



NR: not reinforced
R&NoC: reinforced, but no connection
R&C: reinforced & connected
- GRS Integral Bridge -
No settlement, so no bump !
→ the ultimate solution !
R & C: D/H= 0.6 %
Reinforced & Connected (R & C) D/H= 0.2 %
Reinforced & No Connected (R & NoC): D/H= 0.2 %
NR: D/H= 0.6 %
R & NoC: D/H= 0.6 %
NR (no reinforcement): D/H= 0.2 %
S_5
5 cm
H=50.5 cm
Residual settlement of the backfill at 5 cm back of the facing, S_g/H (%)
Number of loading cycles, N (cycles)
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200

GRS Integral Bridge model for shaking table tests

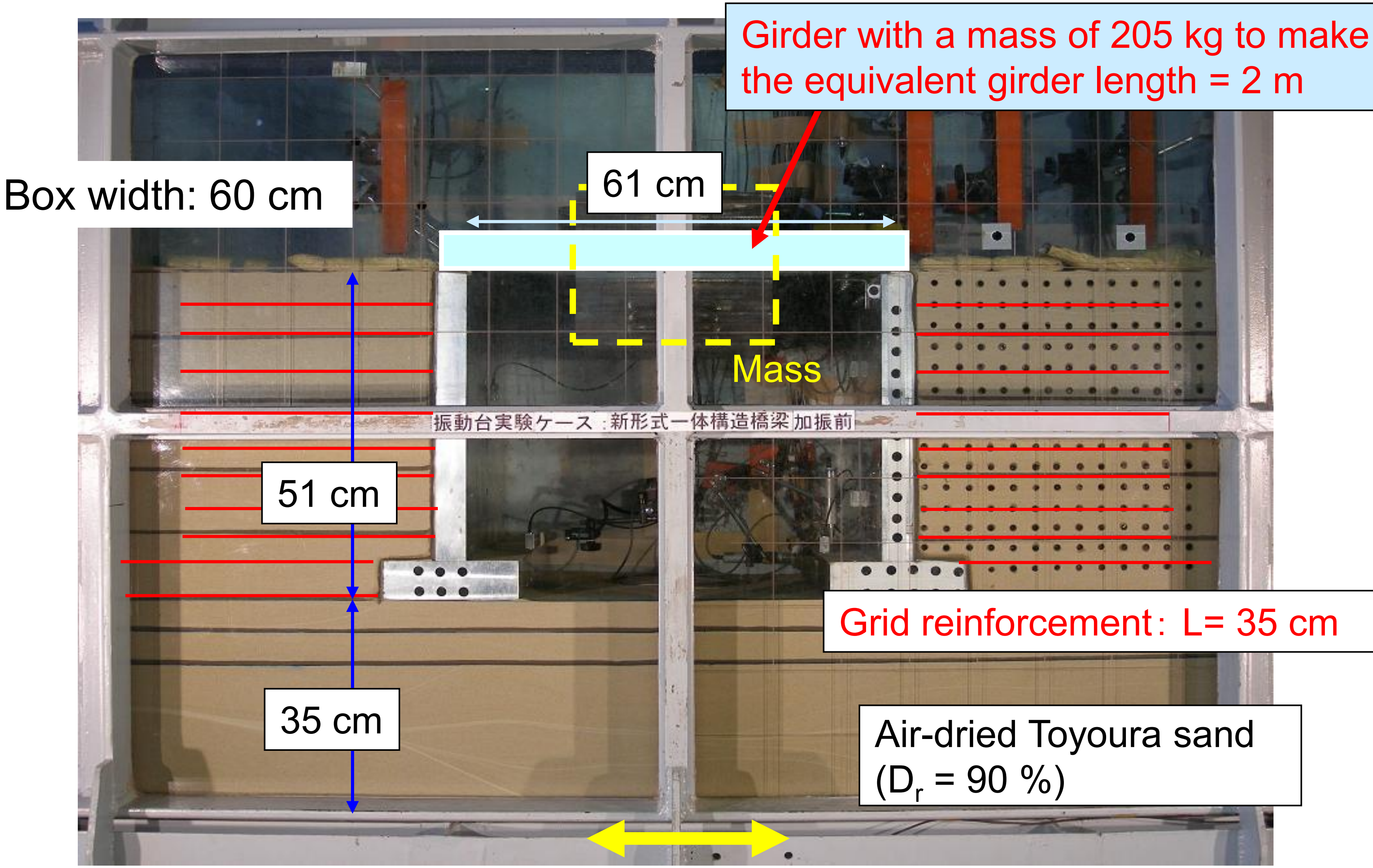
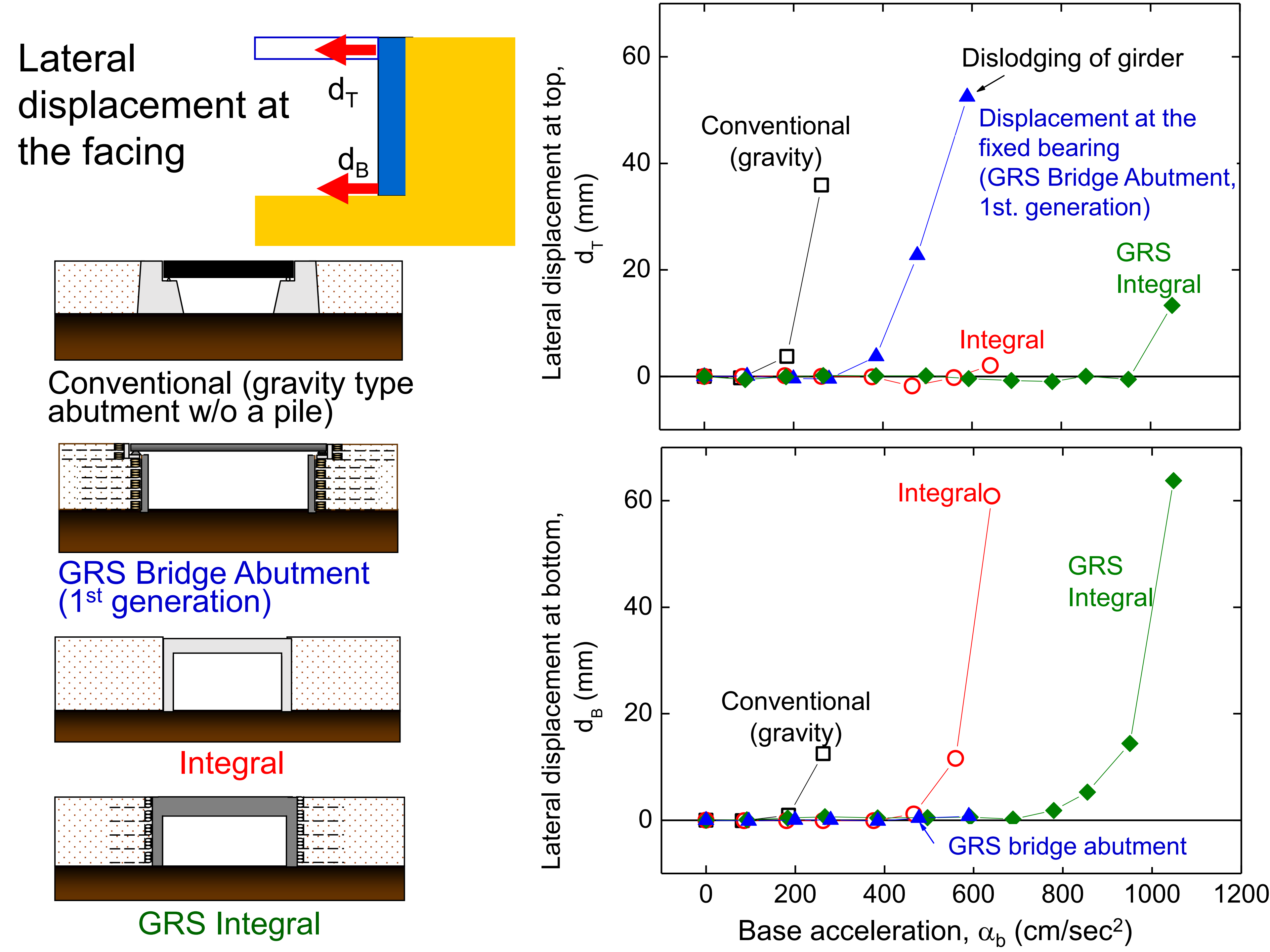
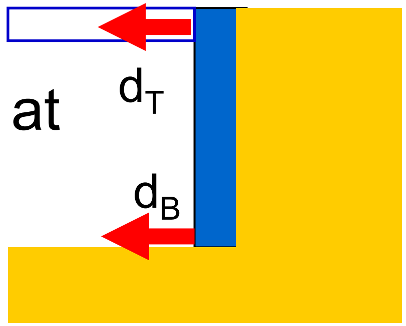


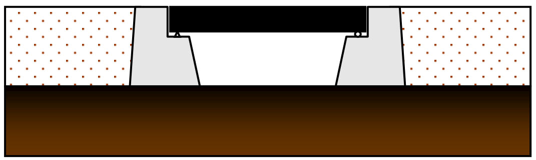
Table acceleration: uniform 20 waves (f_i= 5 Hz) at each step, increasing the amplitude, α_b, by an increment of 100 cm/sec^2/step



Lateral displacement at the facing
d_T
d_B
Conventional (gravity type abutment w/o a pile)
GRS Bridge Abutment (1st generation)
Integral
GRS Integral
Lateral displacement at top, d_T (mm)
Dislodging of girder
Conventional (gravity)
Displacement at the fixed bearing (GRS Bridge Abutment, 1st. generation)
GRS Integral
Integral
Lateral displacement at bottom, d_B (mm)
Integral
GRS Integral
Conventional (gravity)
GRS bridge abutment
Base acceleration, α_b (cm/sec^2)
0
20
40
60
0
200
400
600
800
1000
1200

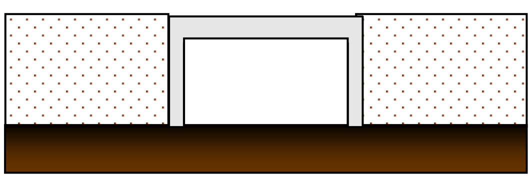
Lateral displacement at the facing



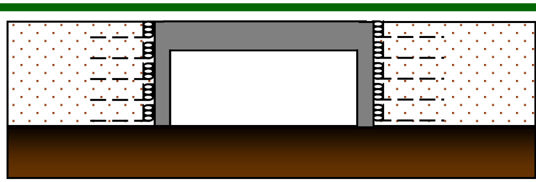


Conventional (gravity type abutment w/o a pile)

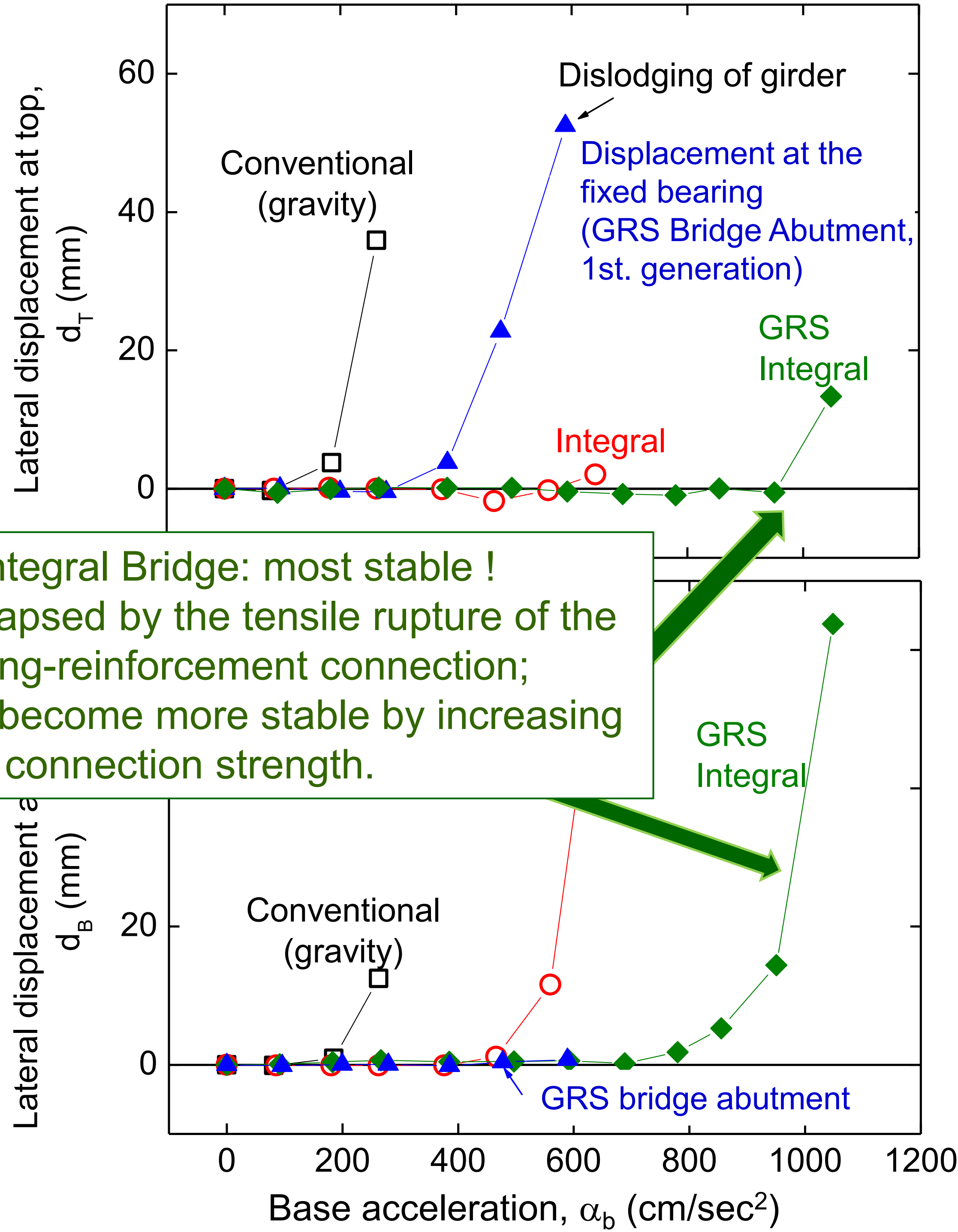
GRS Bridge Abutment (1st generation)



Integral



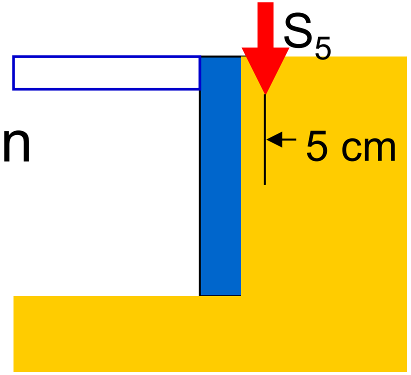
GRS Integral



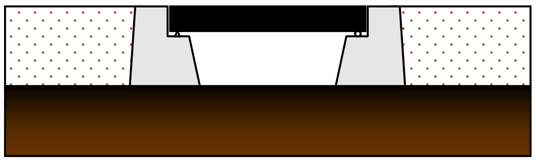
GRS Integral Bridge: most stable !

- collapsed by the tensile rupture of the facing-reinforcement connection;
- can become more stable by increasing the connection strength.

Residual settlement in the backfill

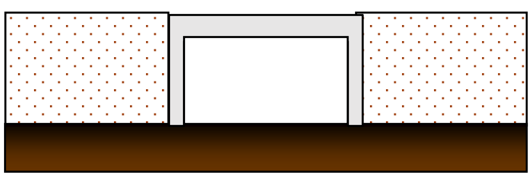


GRS Integral Bridge:
essentially no settlement right behind the FHR facing



Conventional (gravity type abutment w/o a pile)

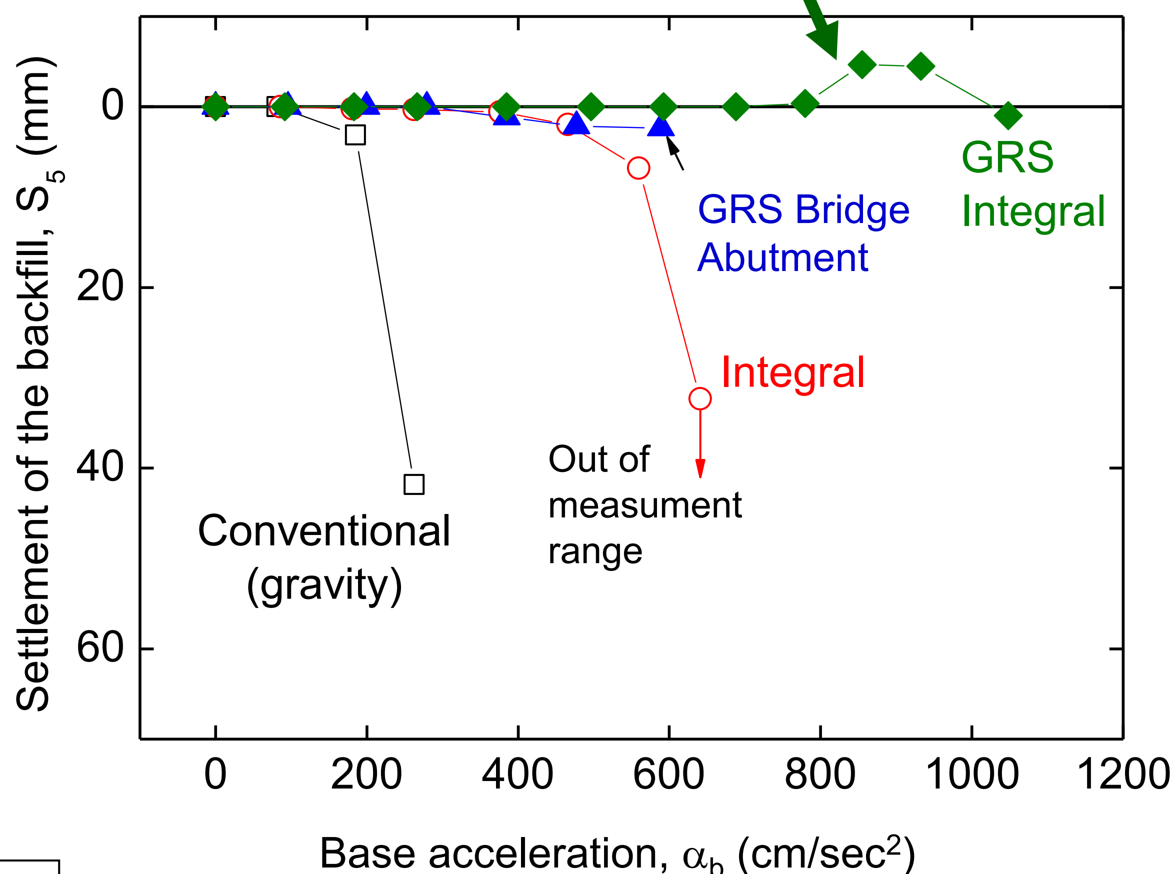
GRS Bridge Abutment (1^{st} generation)



Integral

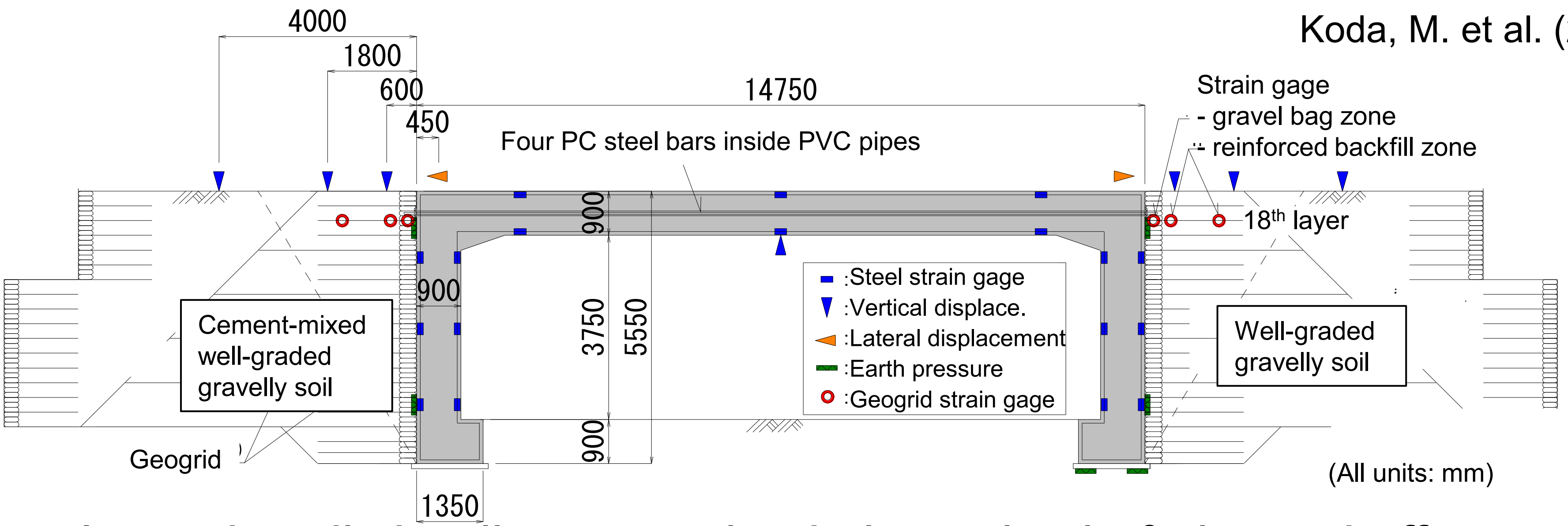
Most stable

GRS Integral



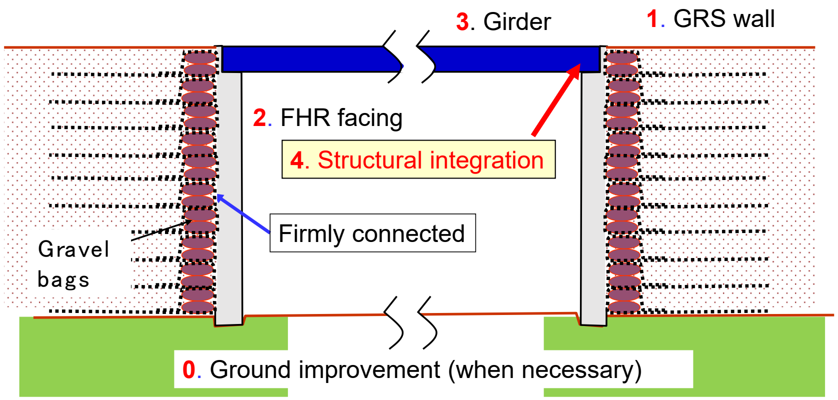
Full-scale model of GRS Integral Bridge, completed Feb. 2009 at Railway Technical Research Institute, Japan

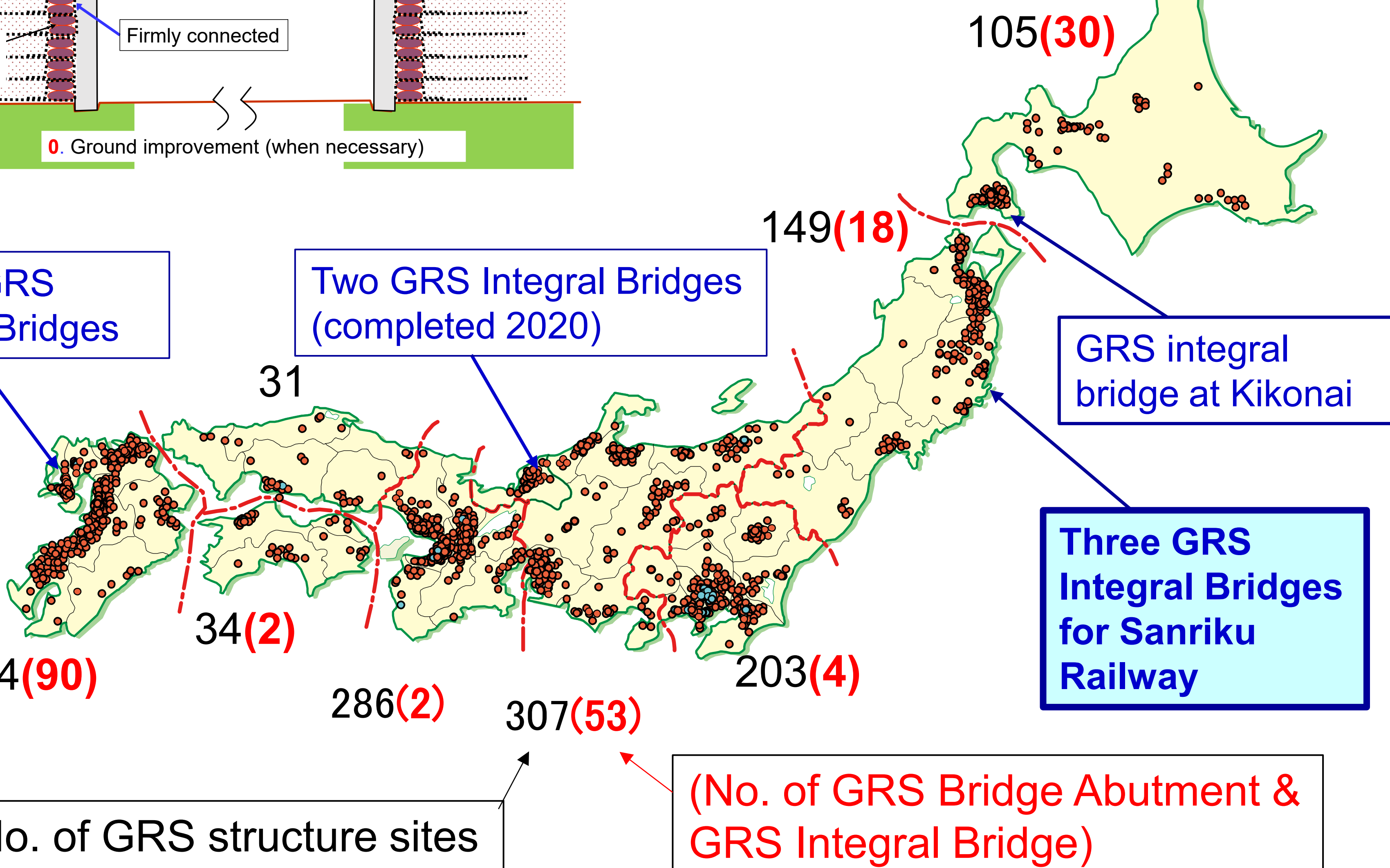
Koda, M. et al. (2018)



Lateral cyclic loading tests simulating seismic & thermal effects

GRS Integral Bridges for railways



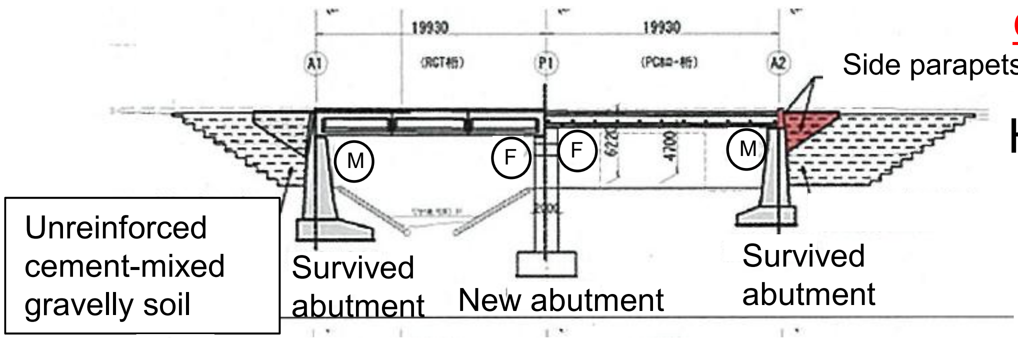


20 days after the 2011 Great East Japan E.Q. (11 March 2011), Koikoreobe, Sanriku Railway

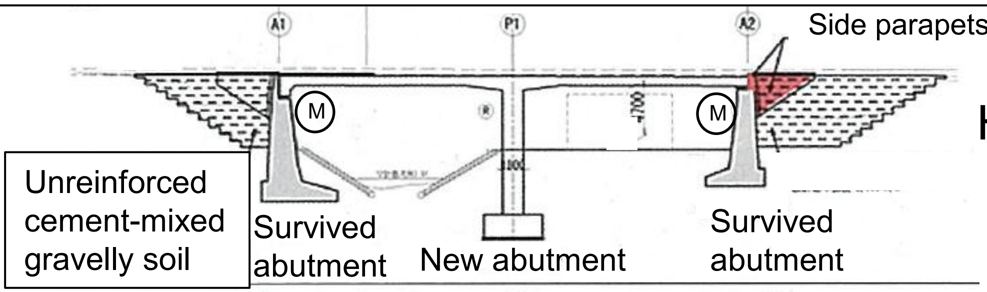
Two simple girders had been washed away towards the inland by a great tsunami from Pacific Ocean

Three proposals for restoration

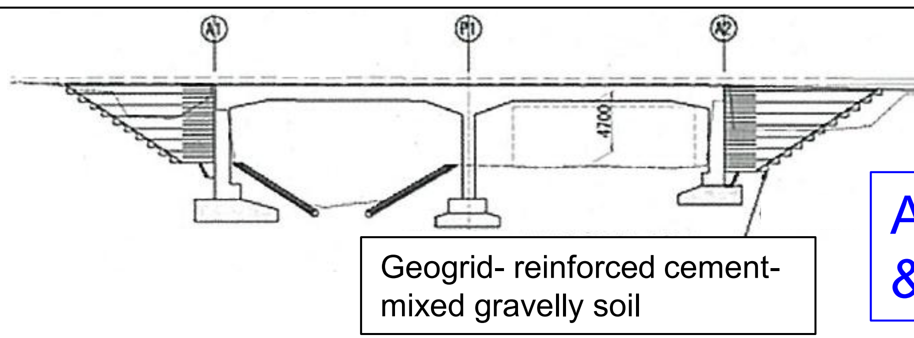
Two-span simple girders with two pairs of bearing M & F, the same as the collapsed one



Single continuous girder with a pair of bearing



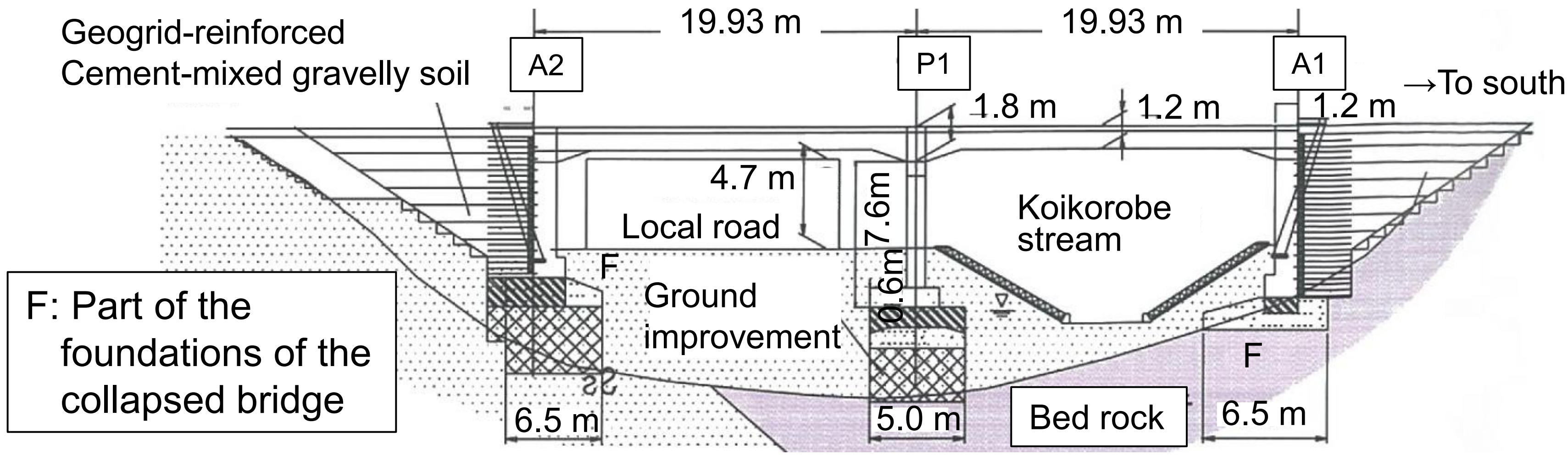
GRS Integral Bridge without using bearings



	Construction cost	Seismic stability	Anti-tsunami stability	Need for maintenance work
Two-span simple girders with two pairs of bearing M & F, the same as the collapsed one	High	Low	Low	High
Single continuous girder with a pair of bearing	High	Inter-mediate	Low	High
GRS Integral Bridge without using bearings	Low	High	High	Very low

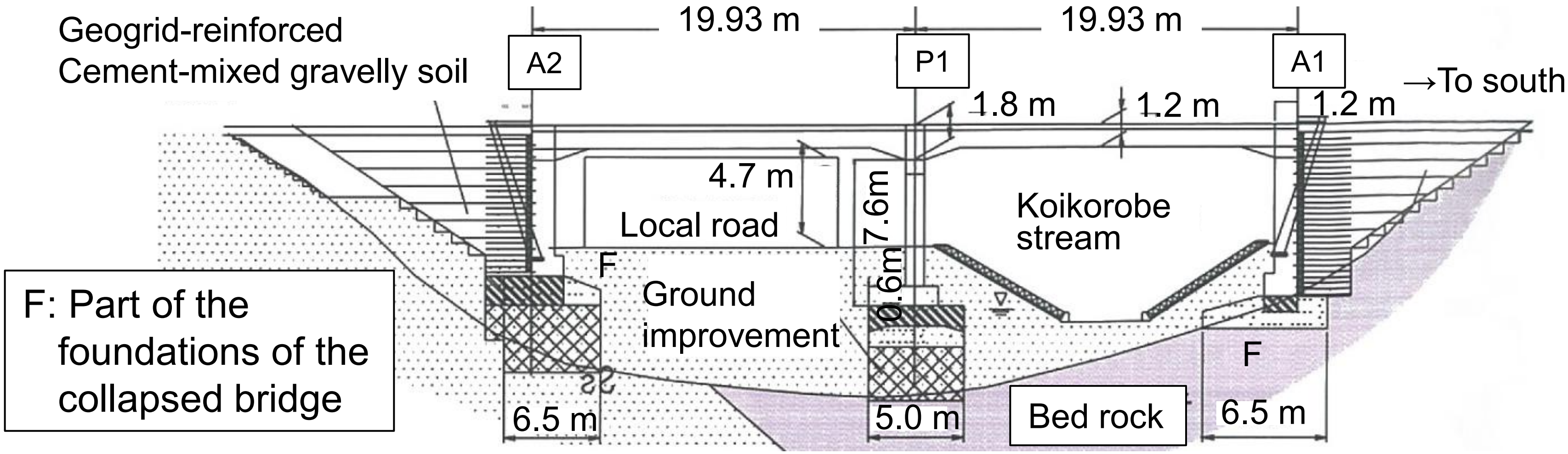
Adopted because of best performance & best cost-effectiveness

GRS Integral Bridge at Koikorobe, Sanriku Railway



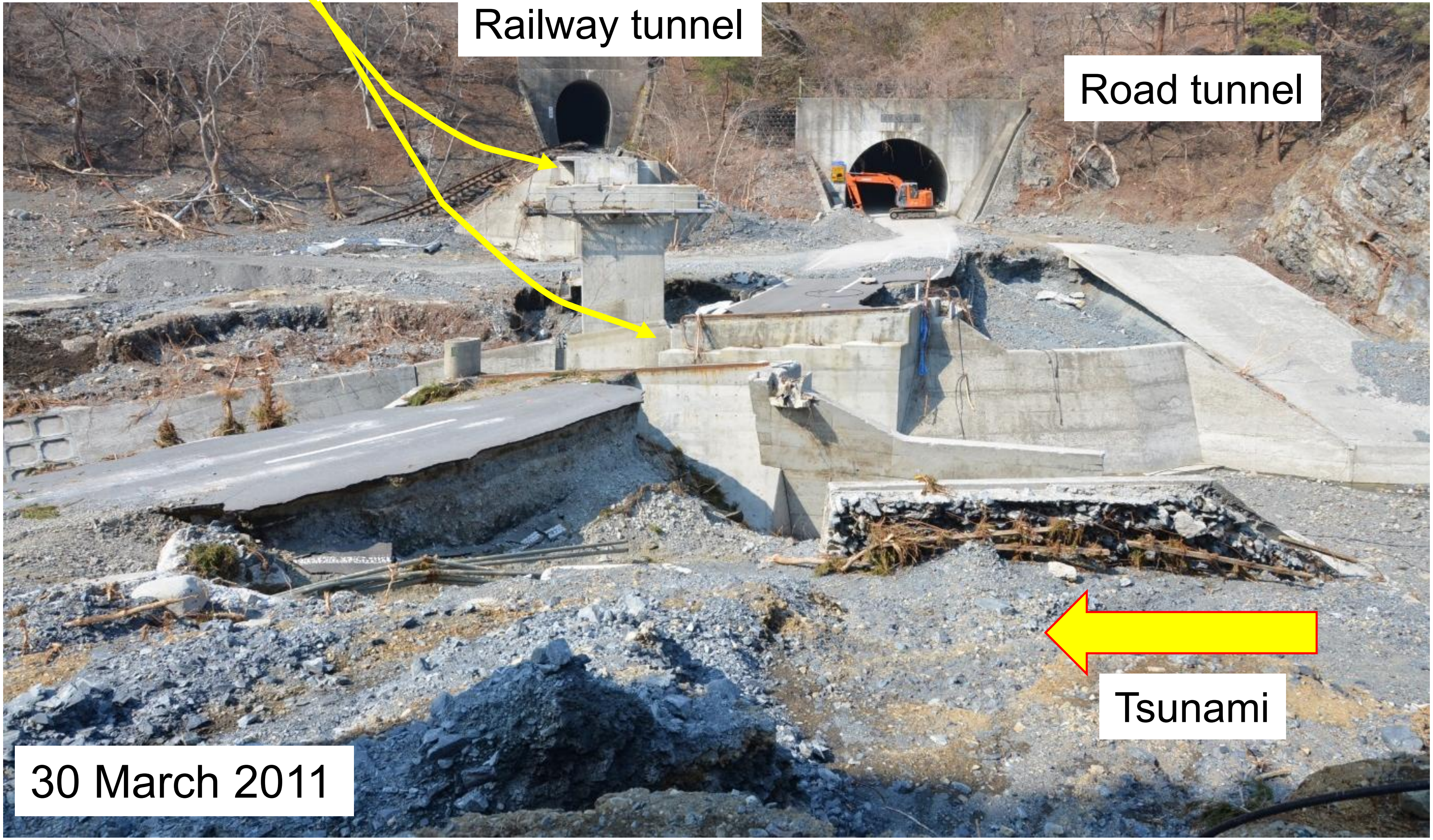
3 November 2013

GRS Integral Bridge at Koikorobe, Sanriku Railway

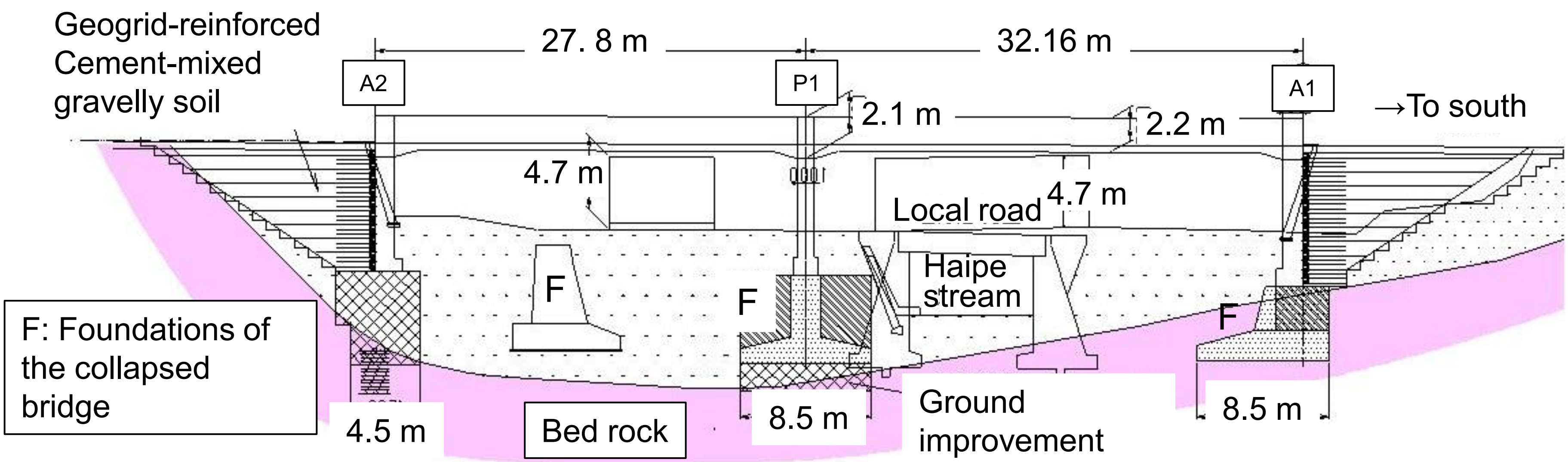


20 days after the E.Q. at Haipe, Sanriku Railway

Two simple girders were washed away towards the inland by a great tsunami from Pacific Ocean (11 March 2011)



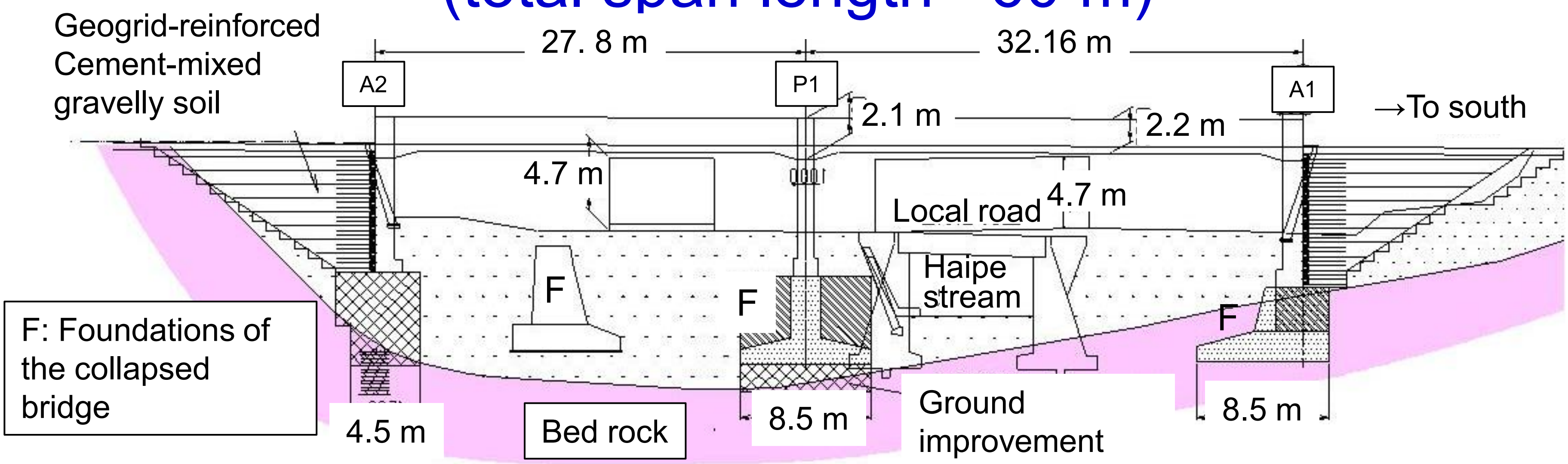
GRS integral bridge at Haipe, Sanriku Railway



GRS Abutment (before the construction of FHR facing)

22 May 2013

GRS Integral Bridge at Haipe, Sanriku Railway (total span length= 60 m)

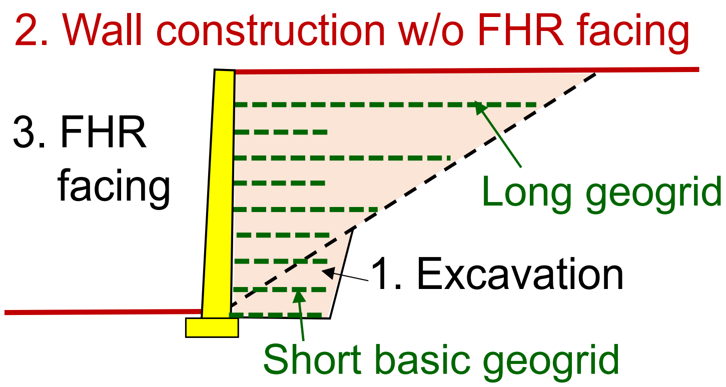


- Slender girder & FHR facing, resulting from structural integration of girder, FHR facing & reinforced backfill
- No bump right behind the facing during long-term service

⇒ A large cost reduction in construction & maintenance

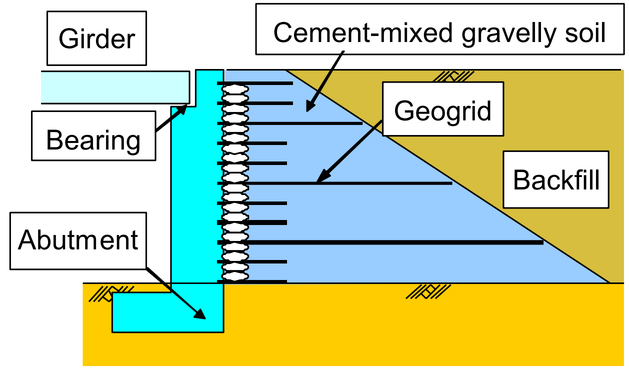
Different patterns of geogrid arrangement

GRS RW: longer geogrid at top



1) Short basic geogrid layers to minimize the slope excavation when the wall is constructed on slope.
2) Several long geogrid layers at upper levels for high wall stability; and high stability of surface soil layers subjected to large traffic loads.
3) Some differences in the stiffness & residual settlement between the reinforced & unreinforced zones do not seriously affect smooth running of train/vehicle in the direction in parallel to wall face

GRS Bridge Abutment: longer geogrid at bottom

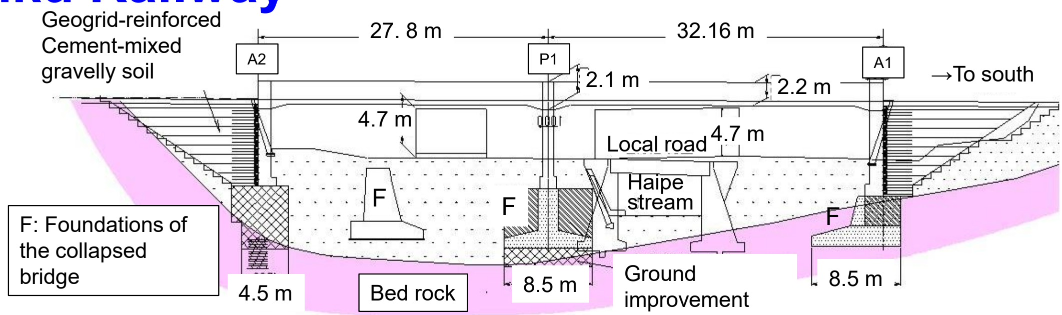


The use of longer geogrid at lower levels:
1) to lower the gravity center of the reinforced zone for high stability against overturning about the facing base by lateral seismic load;
2) to avoid cracking in the brittle cement-mixed backfill that will take place when constructed on deformable unreinforced backfill; and
3) for the thickness of unreinforced backfill to continuously increase from zero when moving away from the RC abutment wall in the direction of railway/road running (i.e., in the direction perpendicular to the RC abutment wall) so that the compression in the unreinforced backfill continuously changes for smooth running of train/vehicle.

Various shapes of reinforced soil zone with actual GRS Bridge Abutments & Integral Bridges constructed under various site conditions…….

GRS Integral Bridge, Haipe, Sanriku Railway

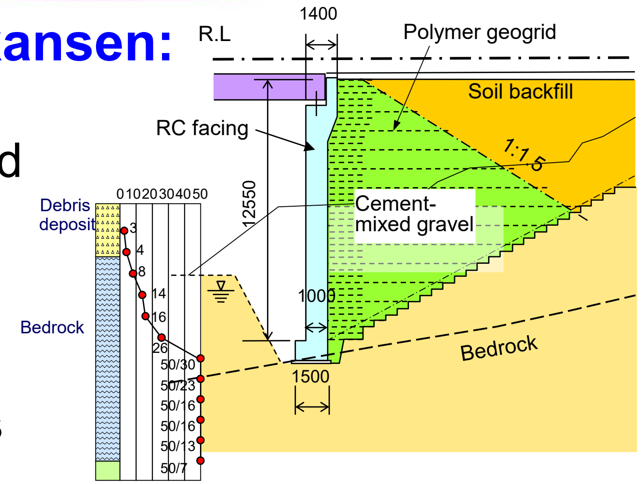
Constructed on very stiff soil or rock slope. Without unreinforced backfill zone in the approach fill, the shape of geogrid-reinforced cement-mixed gravelly soil is reversed-trapezoidal.



GRS Bridge Abutment, Takada, Kyushu Shinkansen:

Constructed on a gentle rock slope.

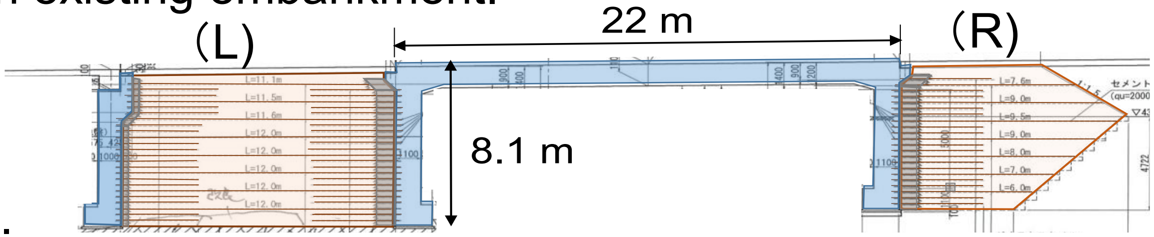
⇒ The bottom part of the trapezoidal geogrid-reinforced cement-mixed backfill zone was truncated.



GRS Integral Bridge & GRS Bridge Abutment, Echizen Hirabayashi, Hokuriku Shinkansen:

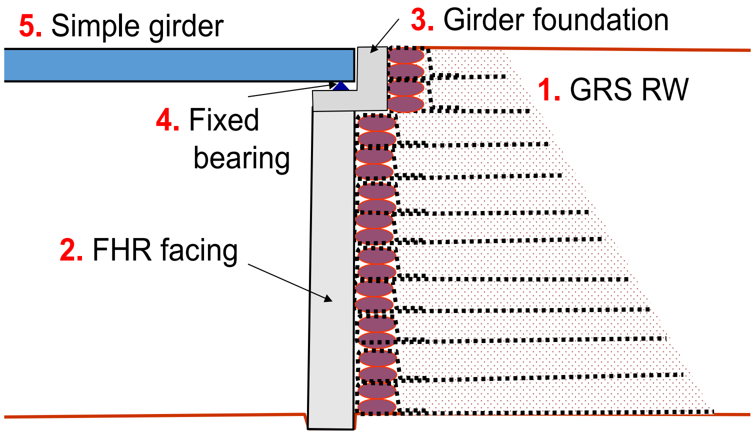
(R) Geogrid-reinforced cement-mixed backfill zone was made wide while the bottom zone was truncated to reduce the excavation in an existing embankment.

(L) Two reinforced zones for GRS Integral Bridge and GRS Abutment are unified to a single reinforced zone.

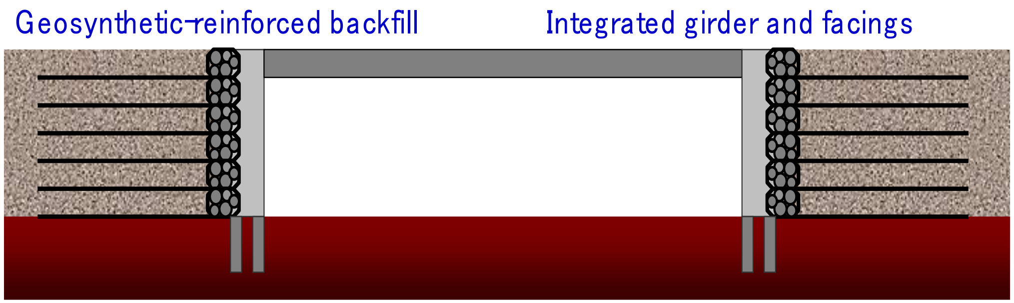


All the GRS bridge abutments are designed based on the stability analysis.

Summary:



GRS Bridge Abutment supports one end of a simple girder on a fixed bearing arranged at the crest of FHR facing of a GRS RW.

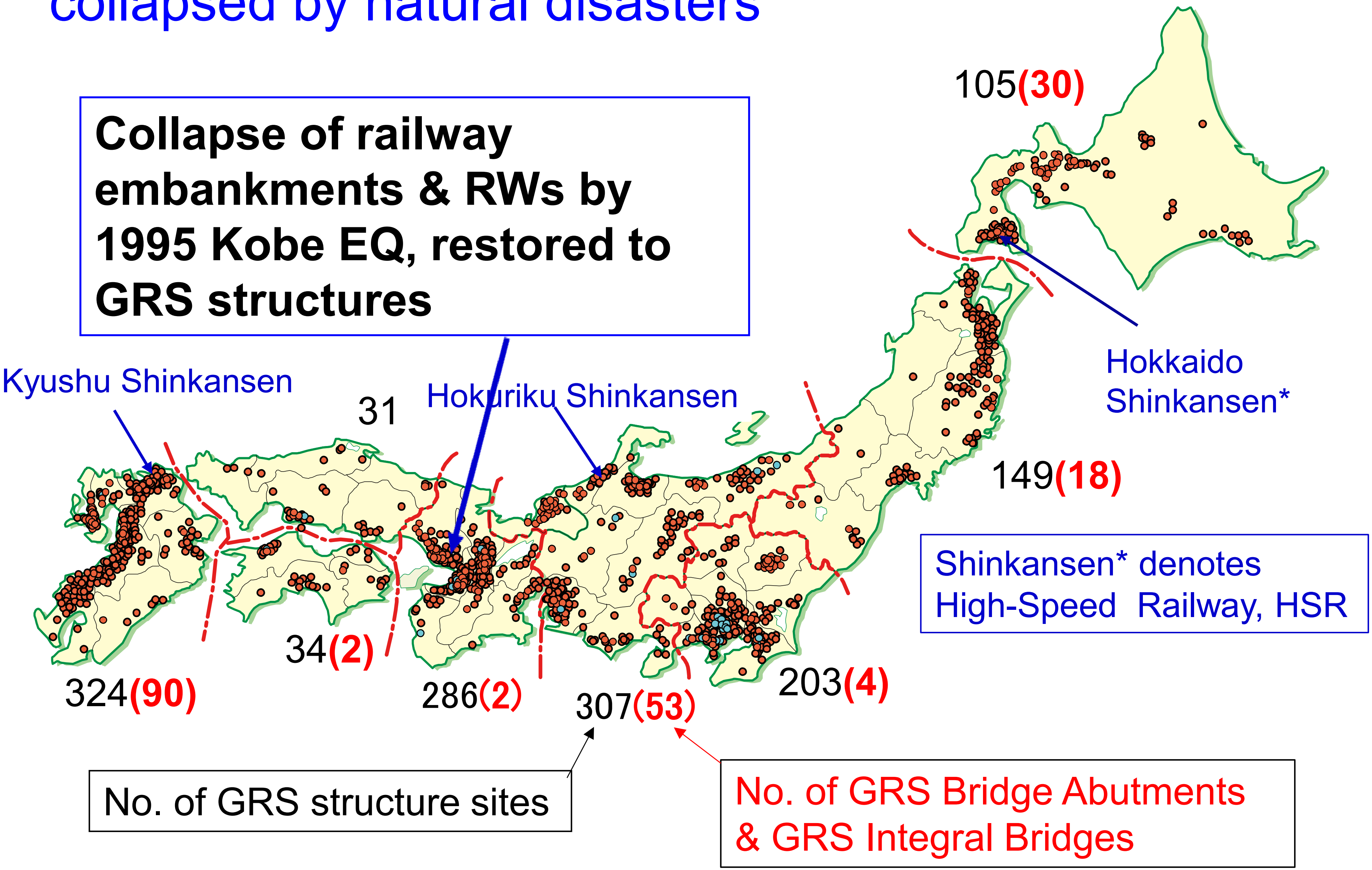


GRS Integral Bridge structurally integrates both ends of a continuous girder to the crest of FHR facings of a pair of GRS RWs, without using bearings.

Compared with the conventional simple girder bridges, these GRS bridge structures are much more cost-effective exhibiting no bump right behind the facing (i.e., vertical RC wall) while much more stable against severe seismic loads, strong floods and tsunamis that may take place during a long period of service. They are now the standard bridge structures for railways including High Speed Railways (Shinkansen).

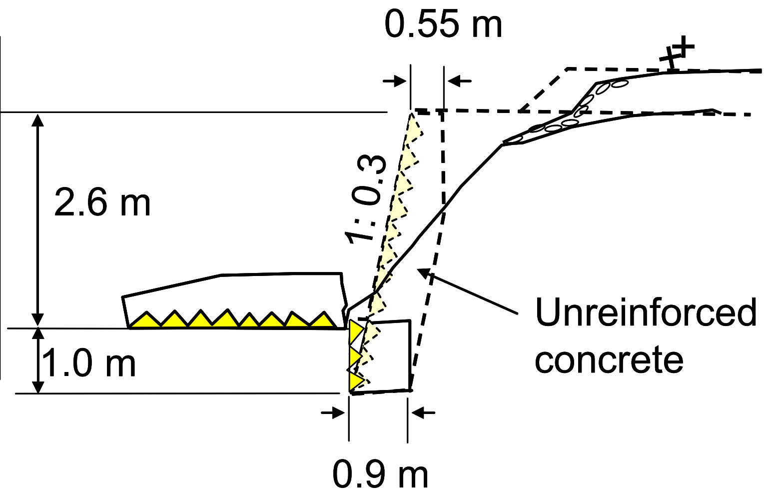
Contents

A number of GRS structures were constructed to restore conventional type soil structures that collapsed by natural disasters



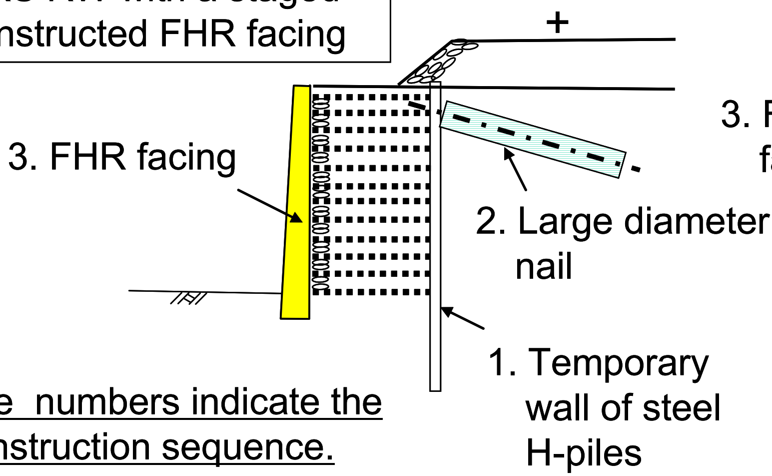
Collapse of gravity RWs by the 1995 Kobe EQ and restoration to GRS RWs & nailed RWs

The EQ took place 5:47 AM
→ no people was walking in front of the wall.

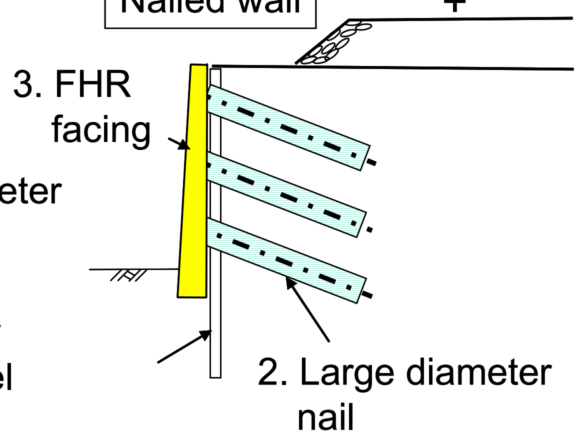


Restoration

GRS RW with a staged-constructed FHR facing

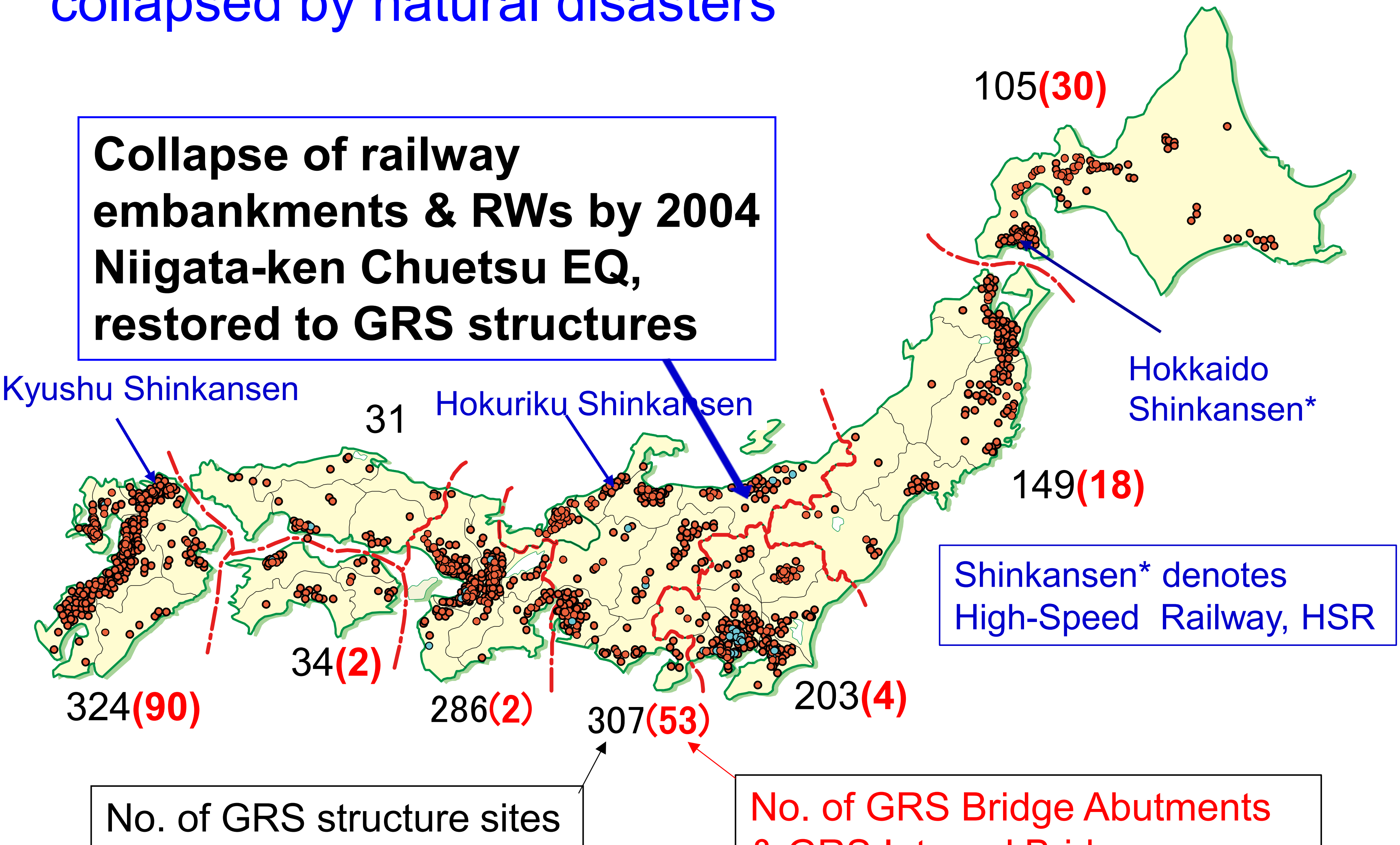


Nailed wall

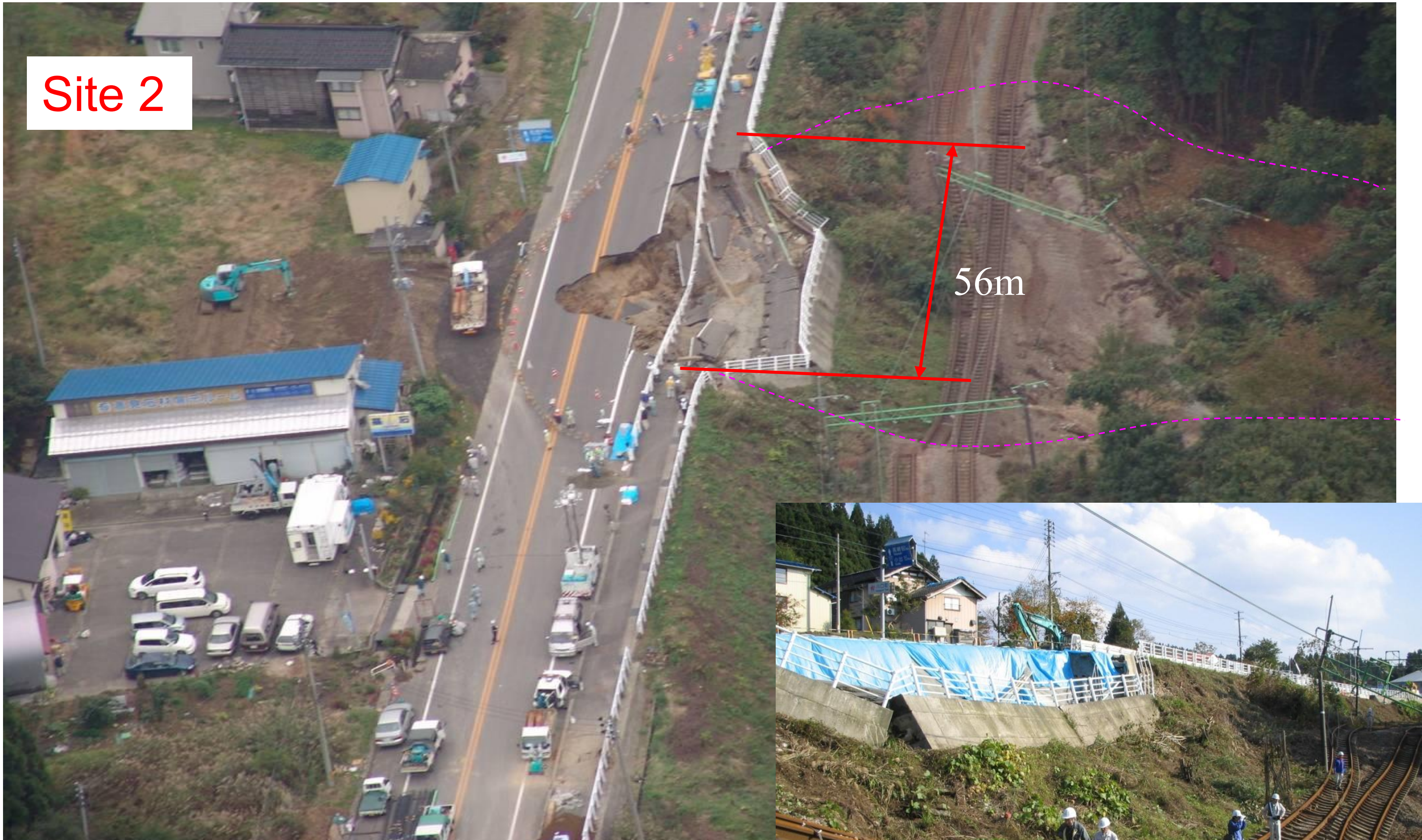


<u>The numbers indicate the construction sequence.</u>

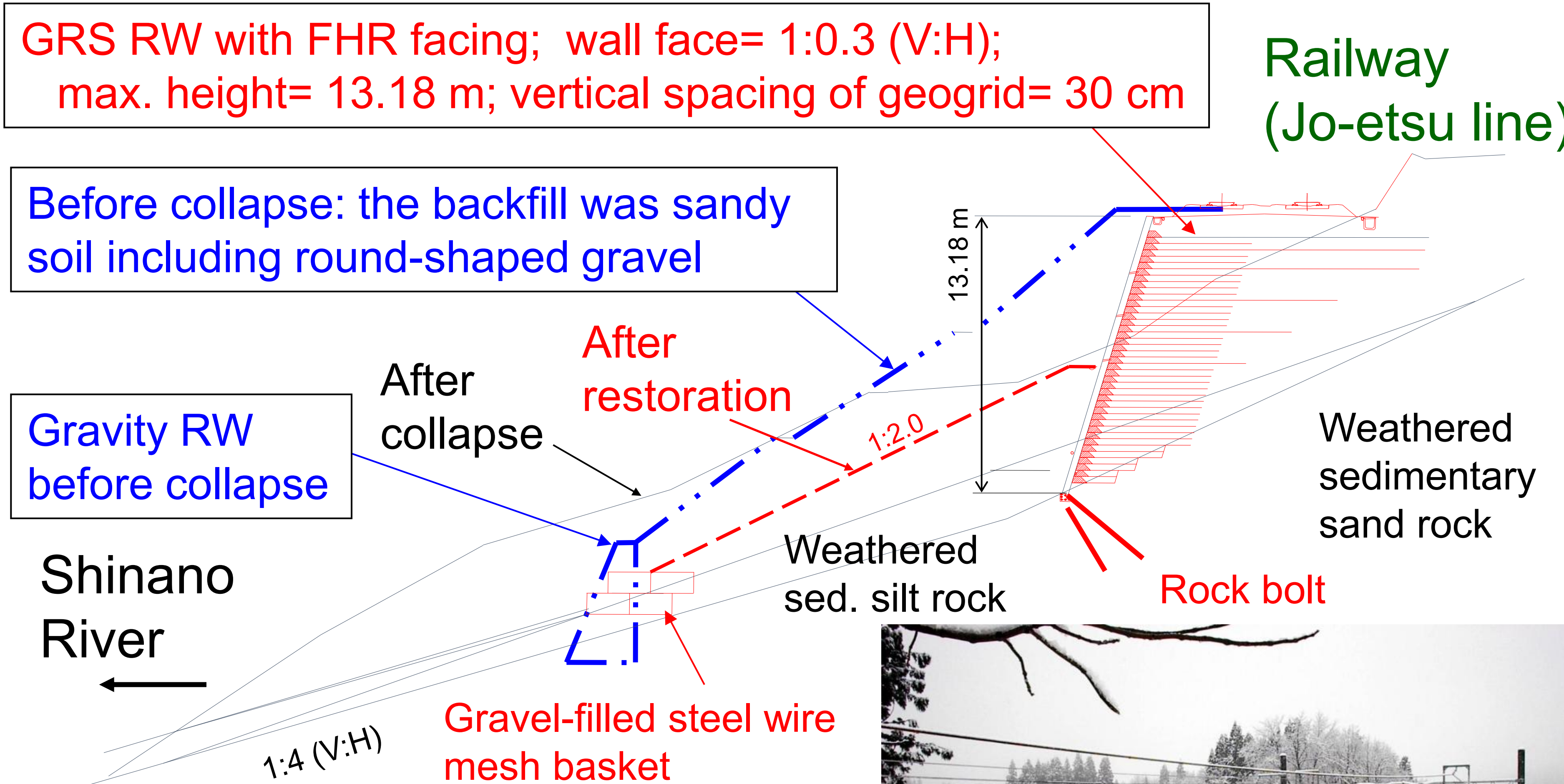
A number of GRS structures were constructed to restore conventional type soil structures that collapsed by natural disasters



2004 Niigata-ken Chuetsu EQ, October 2004



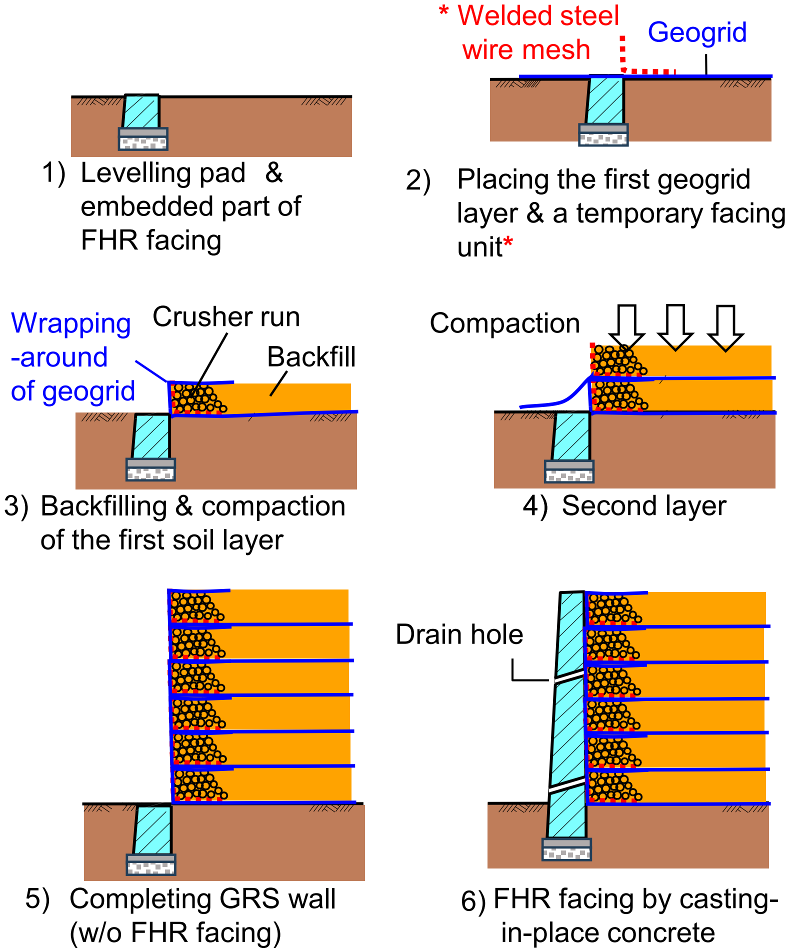
(by the courtesy of Ministry of LITT, Japan)



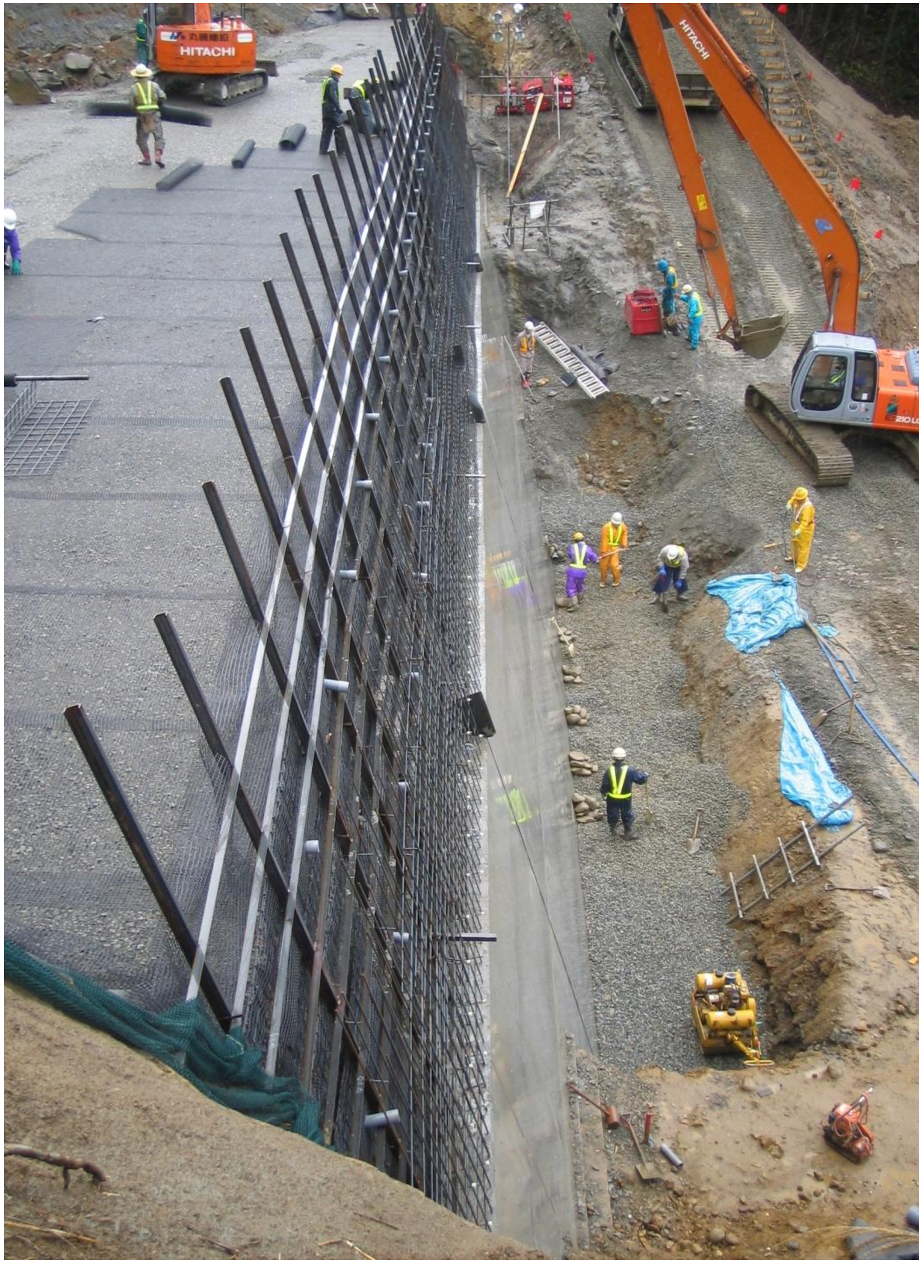
Site 2

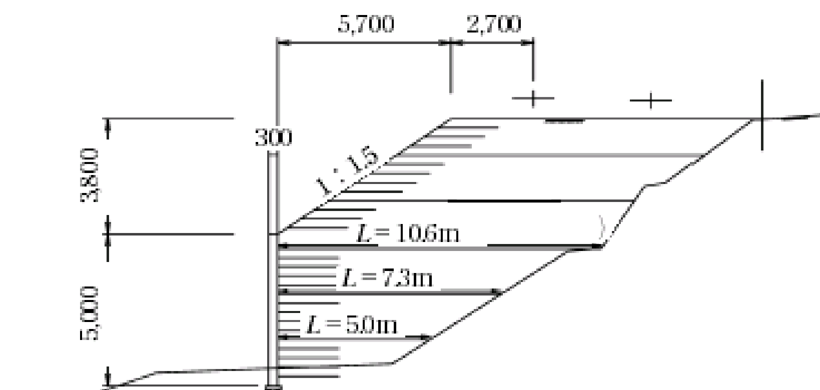
First train

Staged construction of FHR facing



Max. wall height = 13.18 m



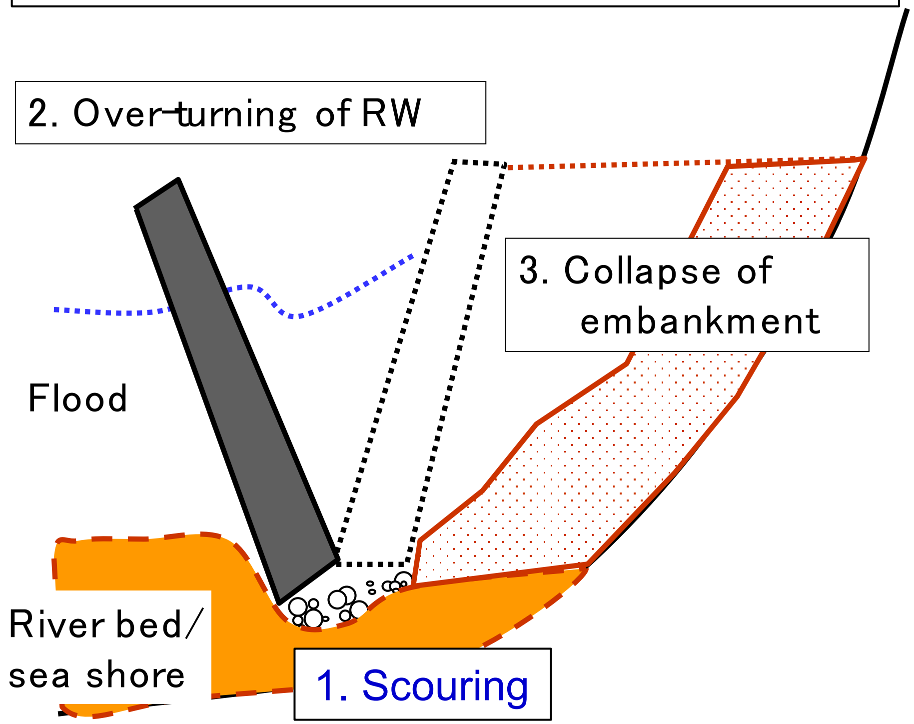


(Unit in mm)

Site 3

Conventional type cantilever RW

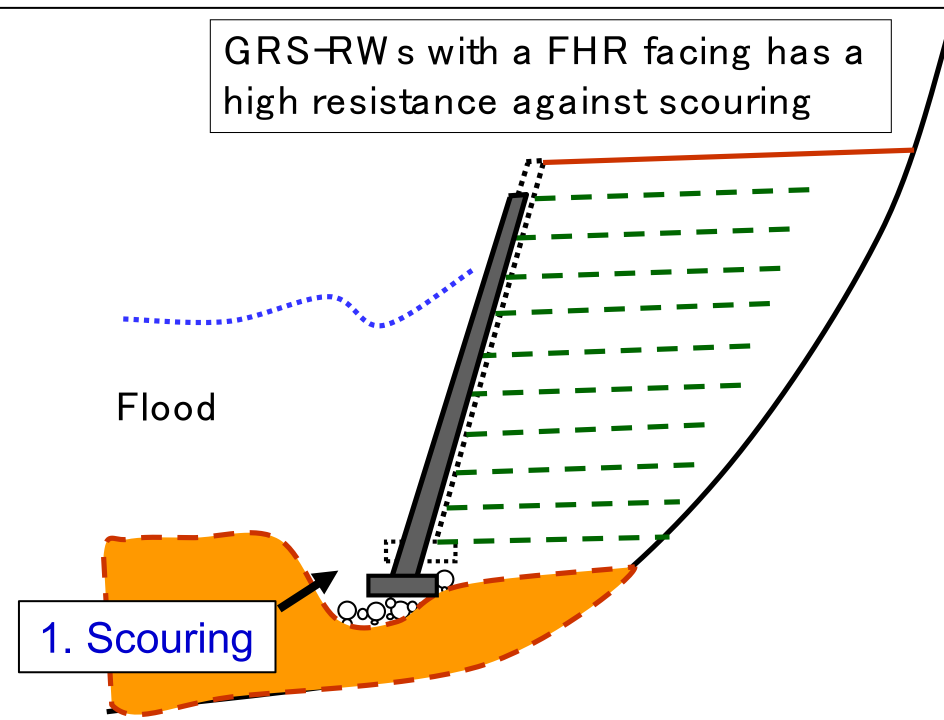
Often, over-turning failure by scouring below the RW structure, quickly resulting into the collapse of embankment



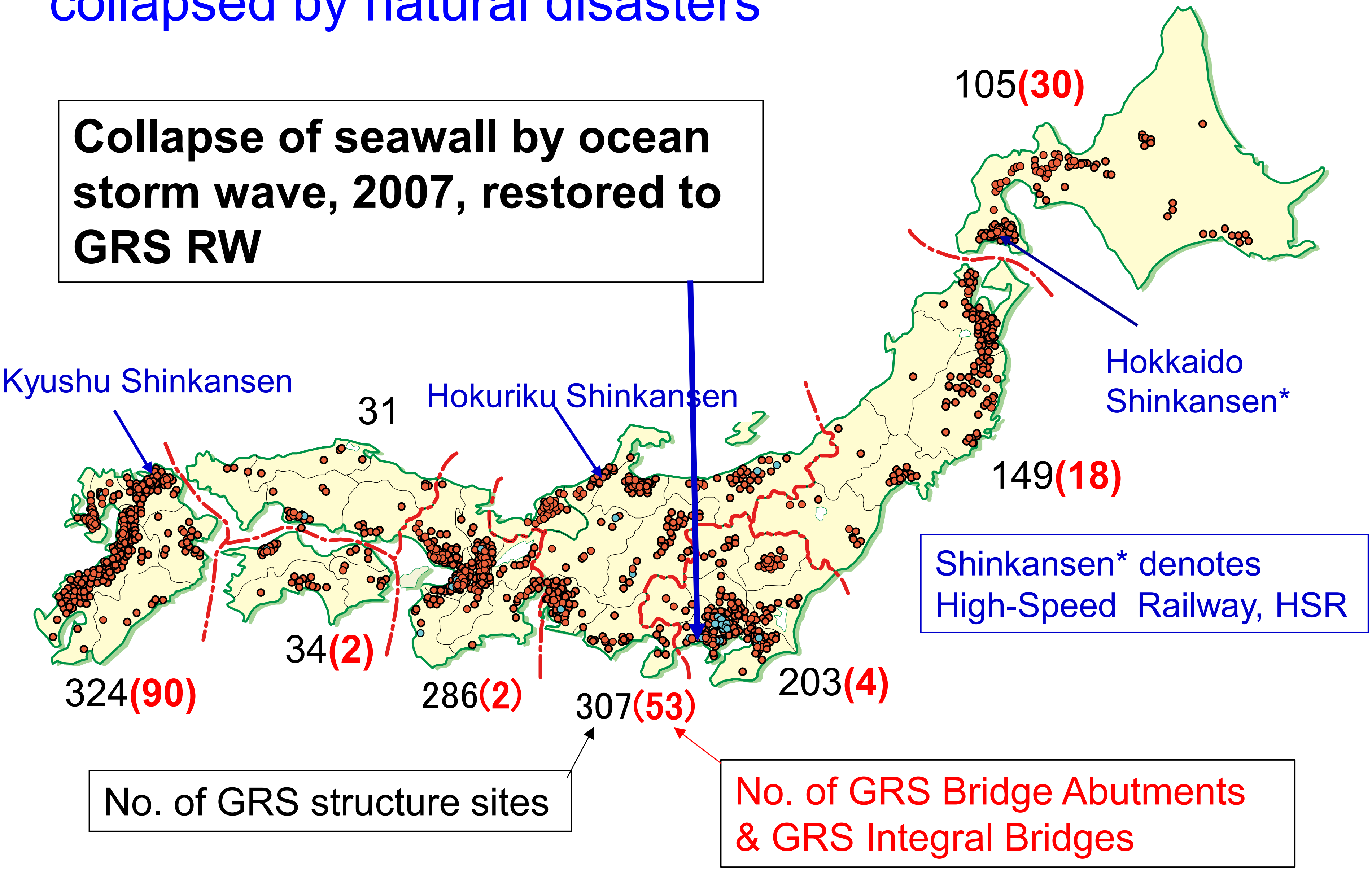
GRS-RW with FHR facing

Much better performance: i.e.,

1) over-turning failure of FHR facing by scouring is difficult to take place; and
2) even if the facing displaces to some extent by scouring, the embankment can survive keeping the function of road or railway.

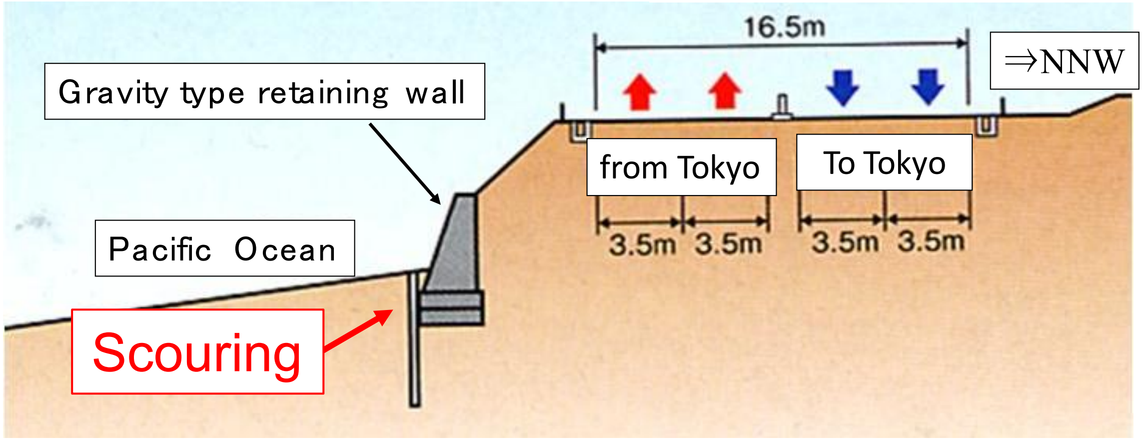


A number of GRS structures were constructed to restore conventional type soil structures that collapsed by natural disasters

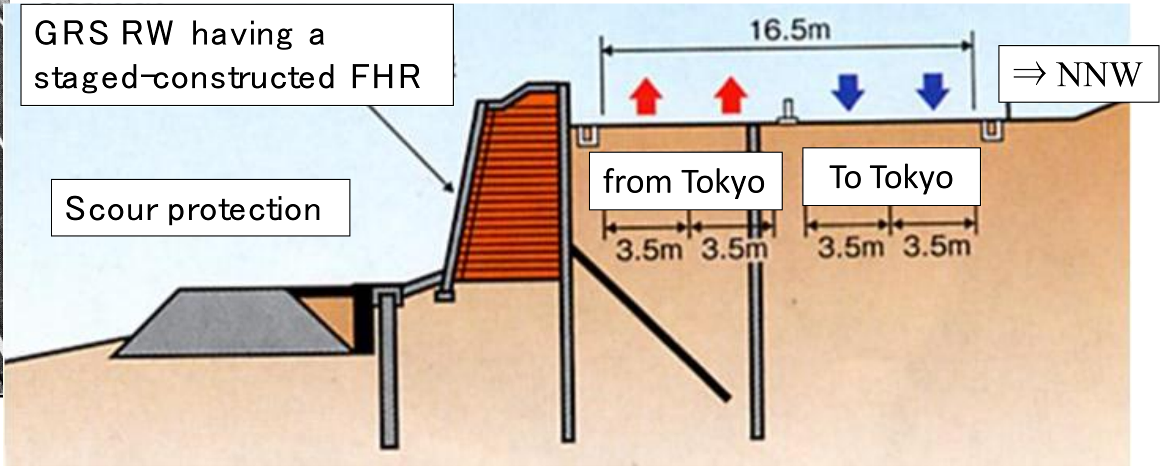


Collapse of gravity-type seawall for a length of 1.5 km by ocean waves during a storm (Typhoon No. 9), 8 Sept. 2007
National Road No. 1, southwest of Tokyo

Before collapse:

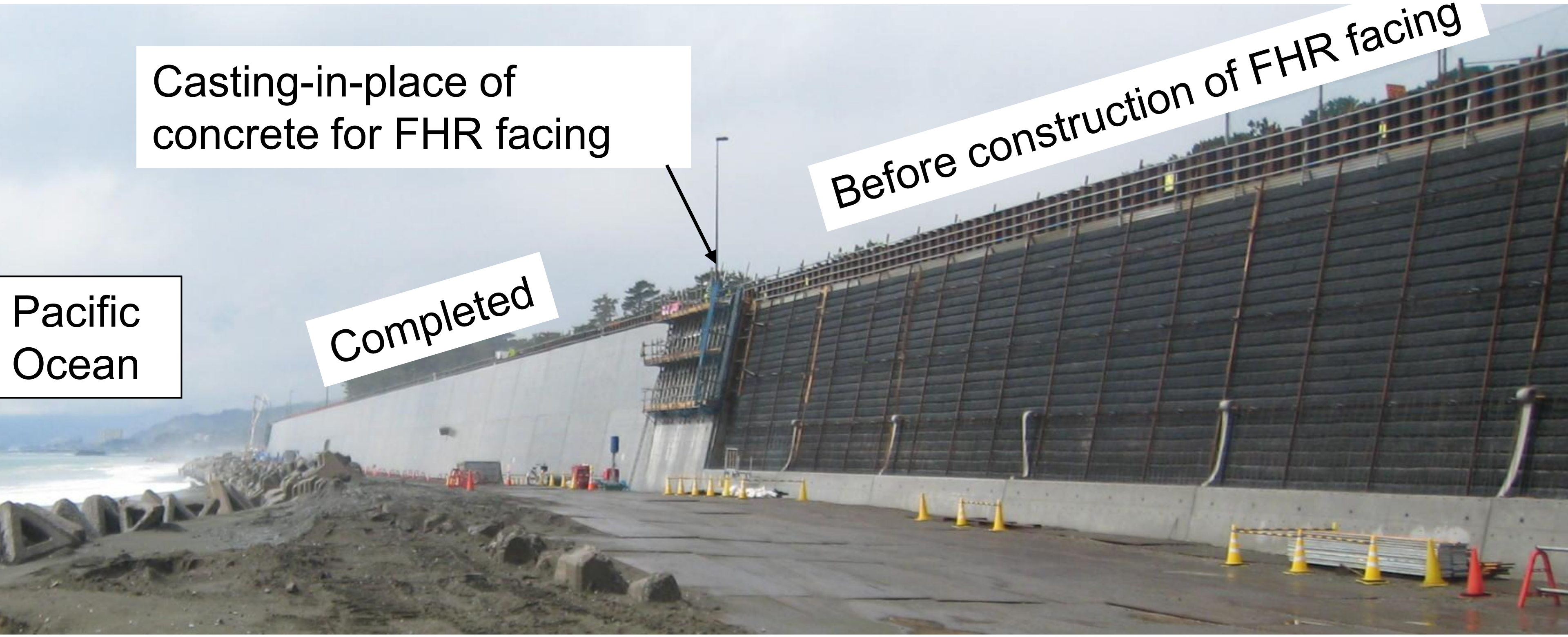


After restoration:



(by the courtesy of Ministry of LITT, Japan)

Restoration to GRS RW with FHR facing



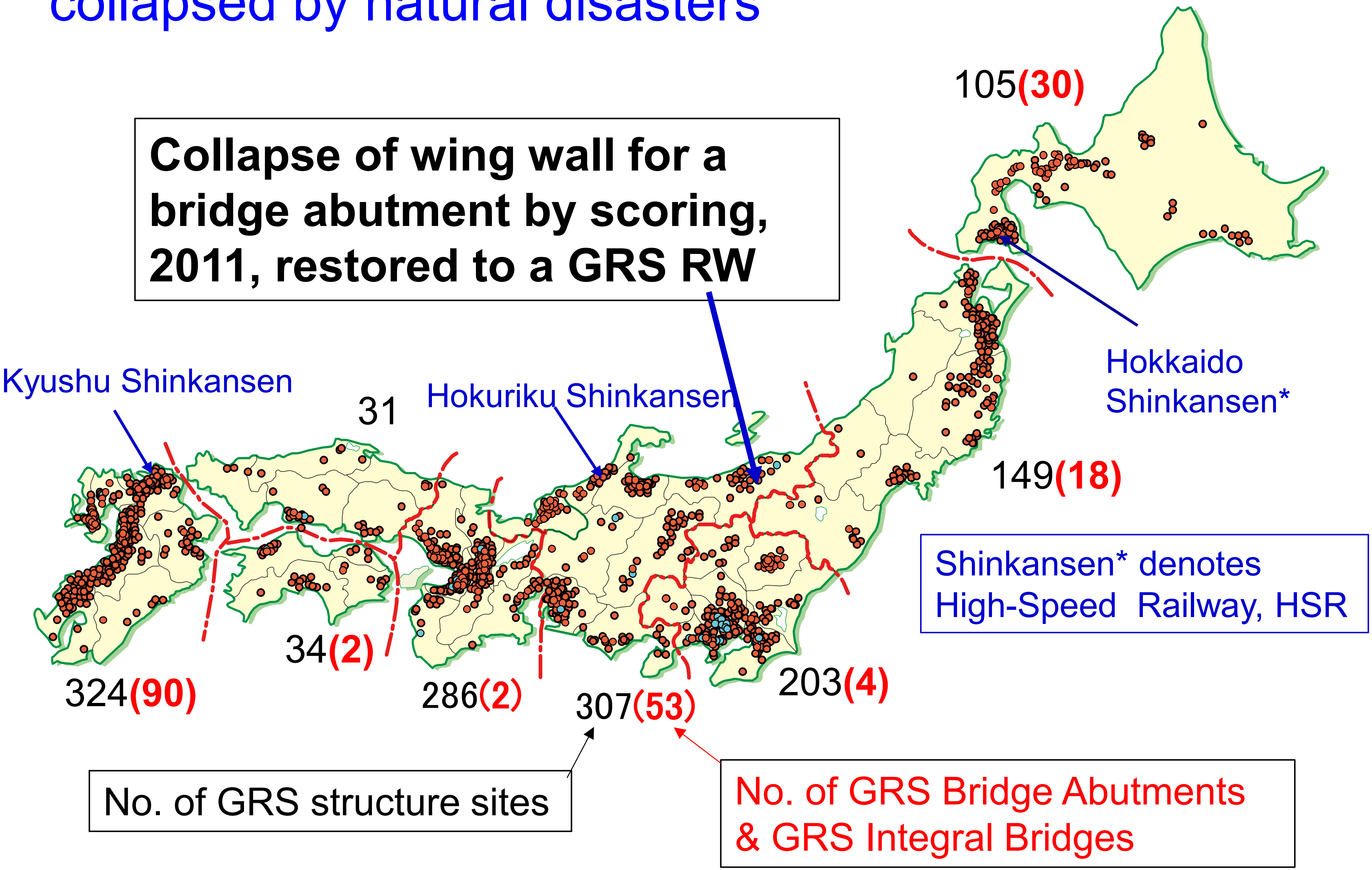
10 March 2010

12 years after restoration to GRS RW

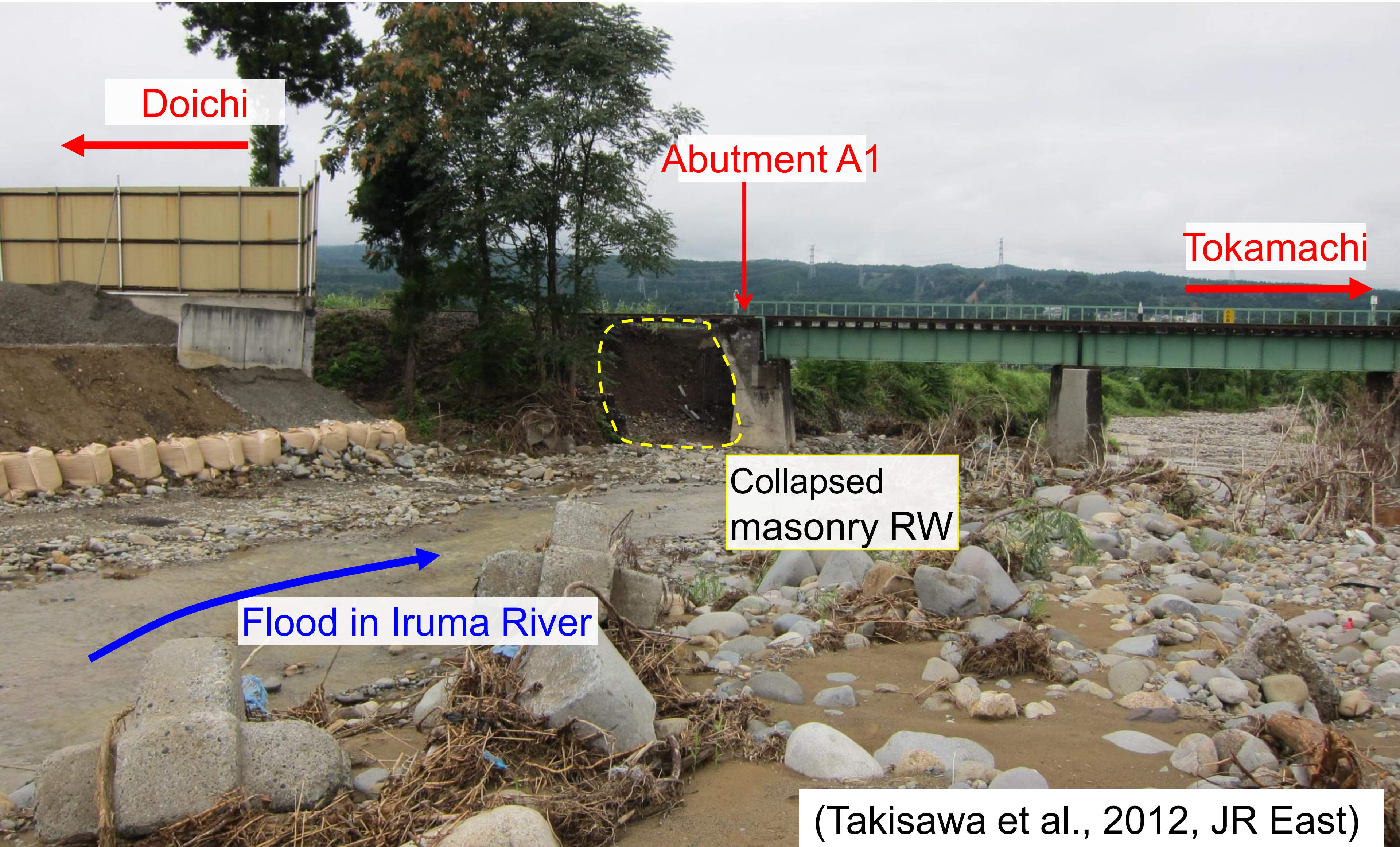
26 Oct. 2023

On average two times per year, ocean storm waves taking in beach sand/gravel particles attack the wall, over-topping the wall

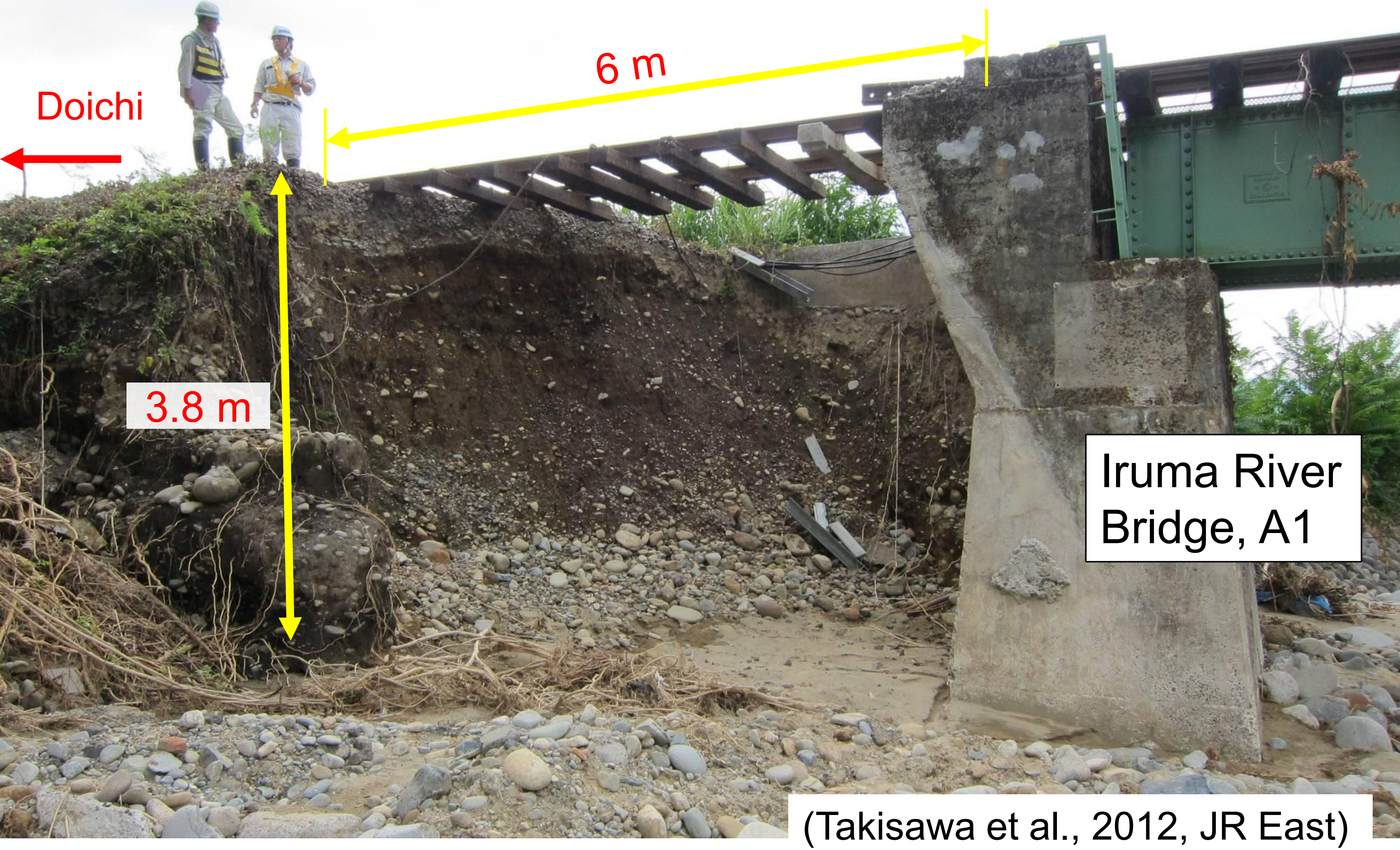
A number of GRS structures were constructed to restore conventional type soil structures that collapsed by natural disasters



Collapse of a masonry wing RW for a RC bridge abutment by scouring in the subsoil and associated erosion of the backfill by river flood, Iiyama Line (JR East), July 2011



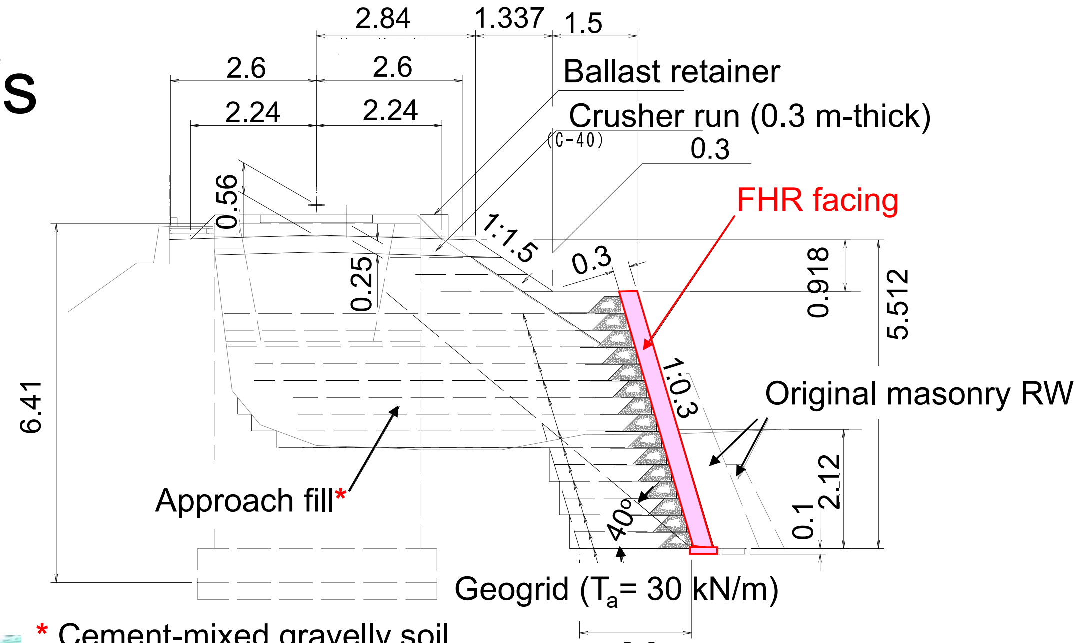
Collapse of a masonry wing RW for a RC bridge abutment by scouring in the subsoil and associated erosion of the backfill by river flood, Iiyama Line (JR East), July 2011



(Takisawa et al., 2012, JR East)

Restoration to GRS RWs

Only 10 days to re-open the service: much shorter than the period required to construct a conventional cantilever RC RW.



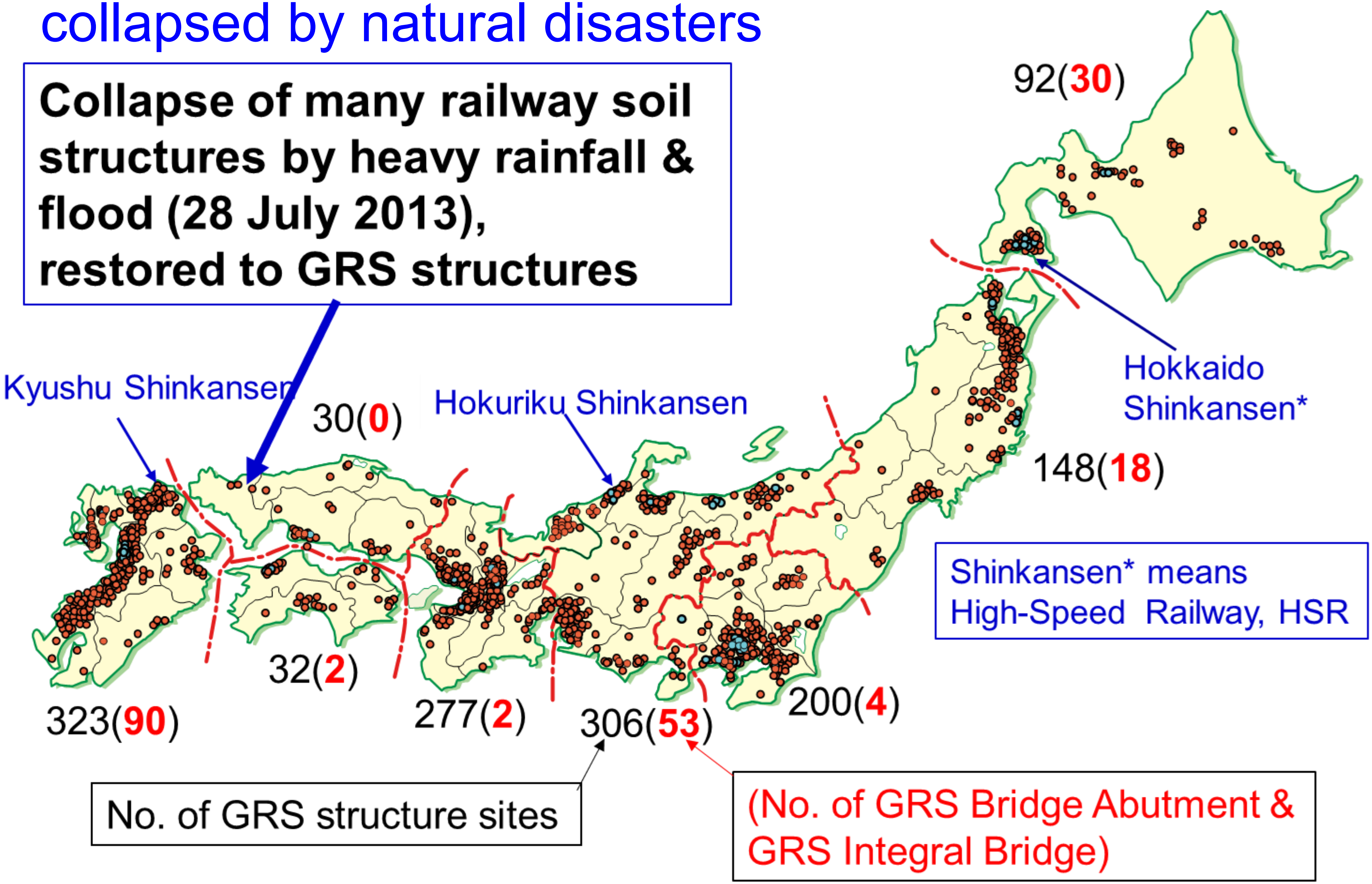
* Cement-mixed gravelly soil, M-40; cement 50 kg/m^3

(All units in m)

(Takisawa et al., 2012, JR East)

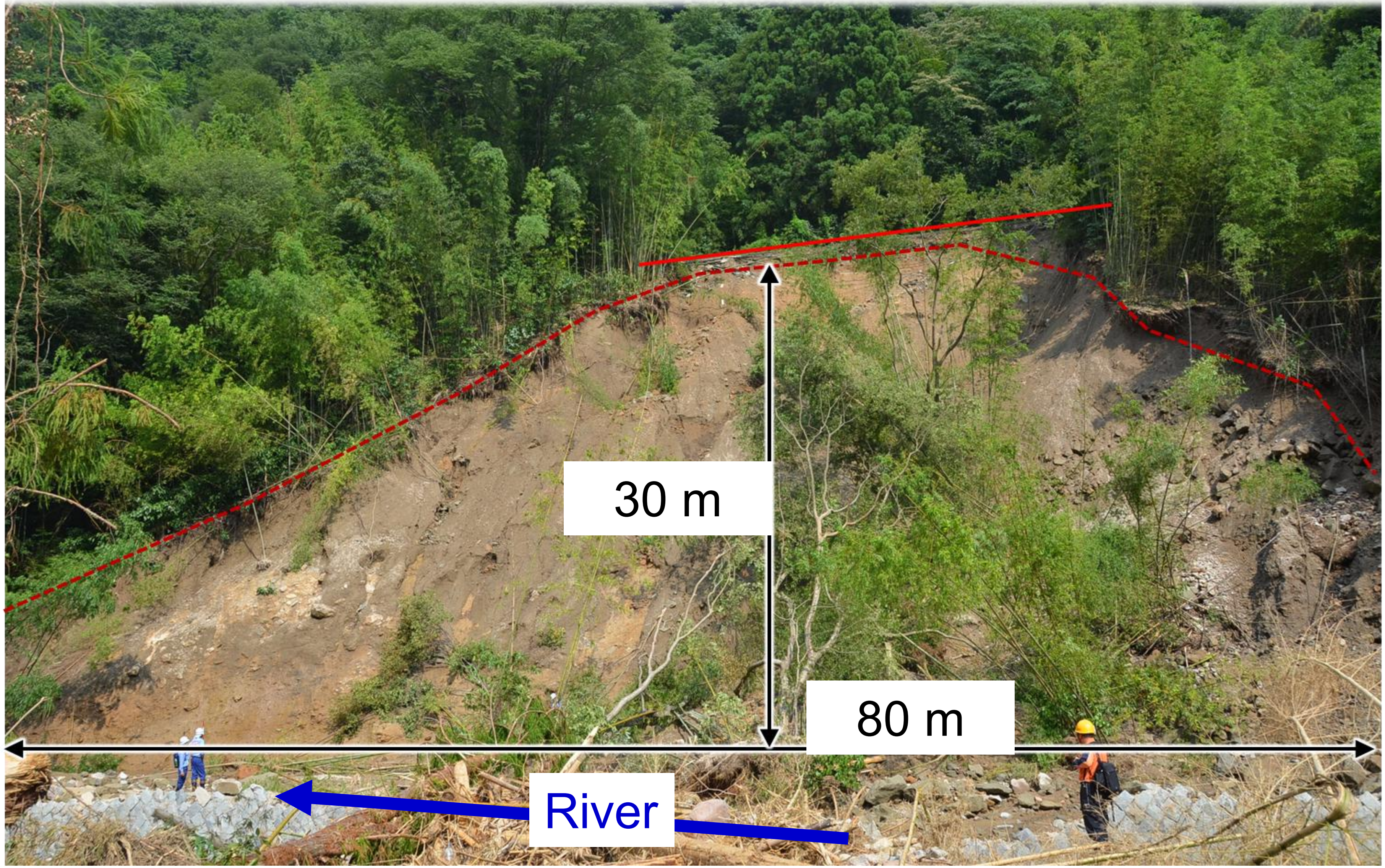
Construction of FHR facing after re-opening of service

A number of GRS structures were constructed to restore conventional type soil structures that collapsed by natural disasters

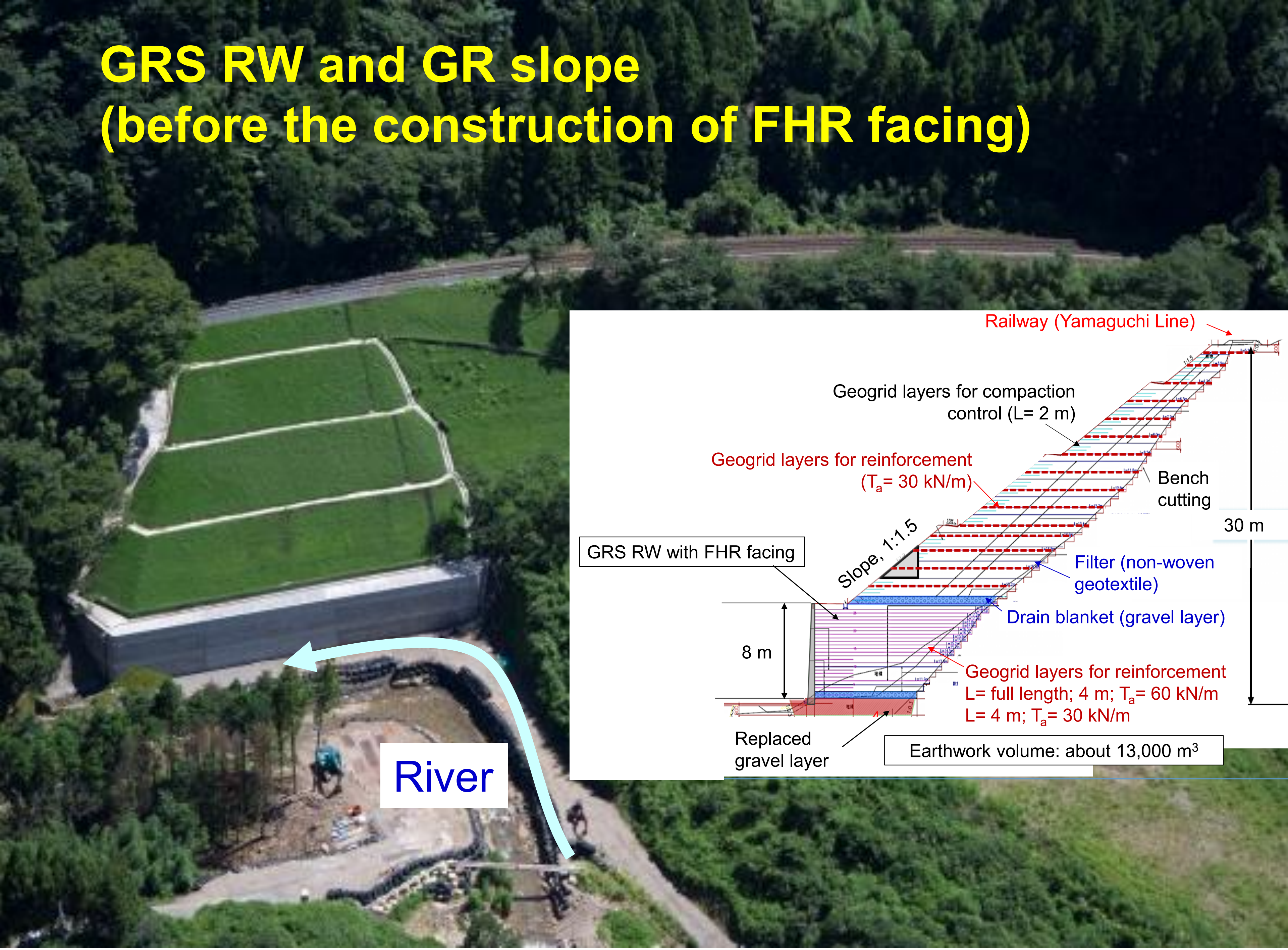


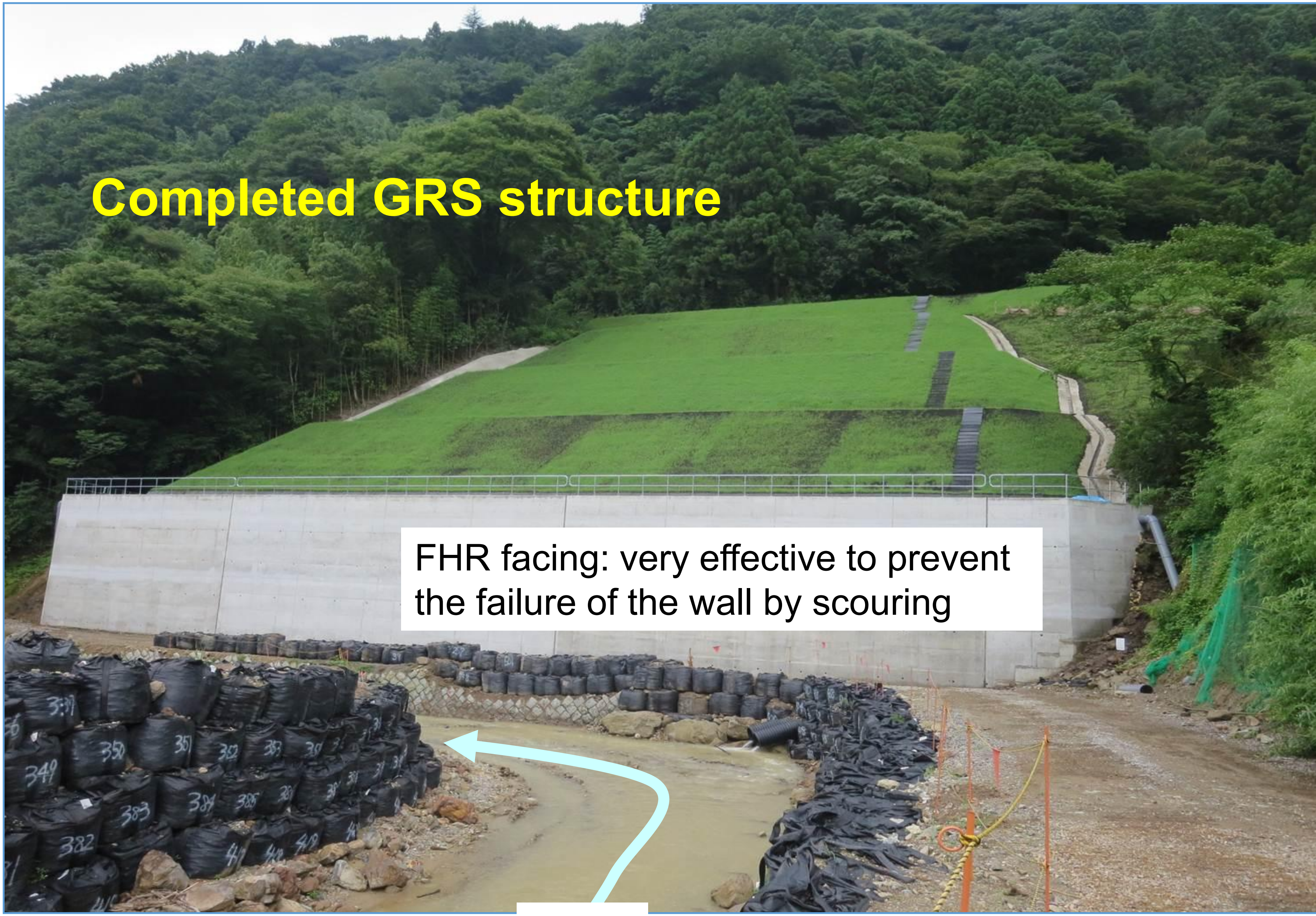
Collapse of railway embankment by scouring at the toe of embankment by river flood (28 July 2013)

JR West



GRS RW and GR slope (before the construction of FHR facing)




Completed GRS structure
FHR facing: very effective to prevent the failure of the wall by scouring
River

Contents

1. Recent GRS structures for High-Speed Railways in Japan

2. Inextensible vs. extensible reinforcement and flexible vs. stiff facing- theoretical & technical background

3. Multiple functions of full-height rigid (FHR) facing

4. Advantages of the construction of FHR facing after the construction of reinforced backfill

5. GRS Bridge Abutment and GRS Integral Bridge

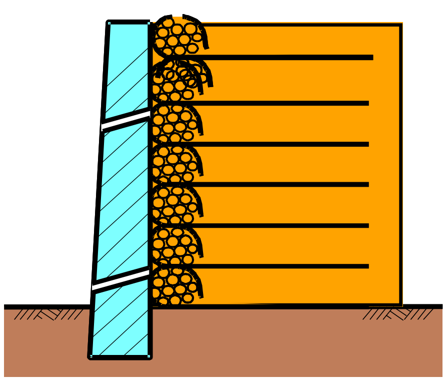
6. Restoration of soil structures that collapsed by earthquakes, floods. ocean storm waves and tsunamis to GRS structures - some other cases

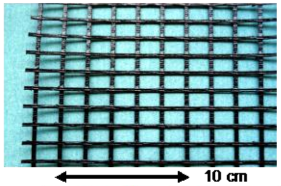
7. Concluding remarks

Concluding remarks – 1/5

A number of **GRS RWs with full-height rigid (FHR) facing, GRS Bridge Abutments, GRS Integra Bridges etc.** have been constructed as important permanent structures for a total wall length more than 221 km as of April 2025. Many of them are for high-speed railways (Shinkansen) and also part of them for roads. This success is due to:

- **high performance** during long-term service and against severe earthquakes, heavy rainfalls, strong floods, tsunamis etc.; and
- **low cost** for construction and long-term maintenance.

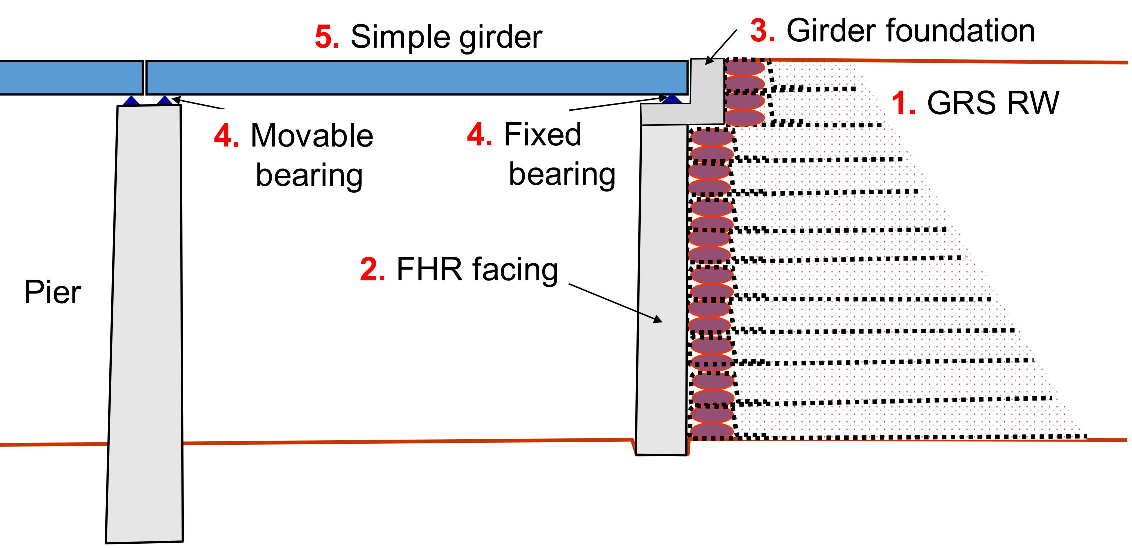




Typical polymer geogrid

Concluding remarks – 2/5

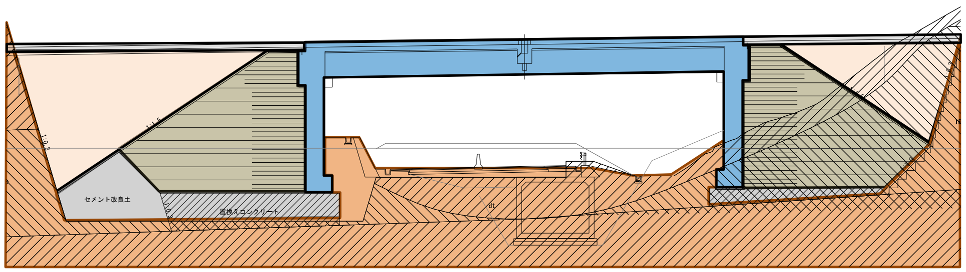
GRS Bridge Abutment supports one end of a simple girder on a fixed bearing arranged at the crest of FHR facing of a GRS RW. This is much more cost-effective and much more stable than conventional type bridge abutments. In total about 200 have been constructed. All of them are performing satisfactorily with essentially zero bump. This is now one of the standard bridge abutment structures for railways in Japan.



Concluding remarks – 3/5

GRS Integral Bridge consists of a continuous girder with both ends being structurally integrated to the crest of the FHR facings of a pair of GRS RWs, not using girder bearings. This is much more cost-effective and much more stable than conventional simple girder bridges. In total 14 have been constructed.

GRS Integral Bridge is now one of the standard bridge structures for railways in Japan.



Concluding remarks – 4/5

Many of the conventional type embankments, RWs and bridges that collapsed by recent severe earthquakes, heavy rainfalls, strong floods, storm ocean waves, tsunamis etc. were restored to GRS structures having FHR facing.

Concluding remarks – 5/5

The followings are **the three breakthroughs** necessary to develop these GRS structures:

1) **The use of full-height rigid (FHR) facing** for changes:
   a) from <u>low earth pressure </u>to <u>high earth pressure </u>on the facing; and
   b) from a secondary non-structural component to a primary structural component.

2) **Staged construction** for changes in the construction sequence:
from <u>the facing before the backfill</u> to <u>the facing after the backfill</u>.

3) **Structural integration of:**
   a) **the FHR facing to the reinforced backfill**; and
   b) also **the girder to the FHR facing for GRS Integral Bridge**,
   for changes from a statically determinate but unstable structures to a statically in-determinate but stable ones.

Thank you very much for your kind attentions.

Acknowledgements

Sincere appreciation for great contributions of many colleagues, students, researchers and engineers who jointed this very long research project at:

University of Tokyo,
Tokyo University of Science,
Railway Technical Research Institute, Japan,
Japan Railway Construction, Transport and Technology Agency,
a number of railway companies,
Integrated Geotechnology Institute Ltd., and
many other consulting and construction companies.

Building the future on new foundations
TOKYU CONSTRUCTION

Typical Construction Case Histories of RRR GRS Structures

Yuichi Tomita
Tokyu Construction, Japan

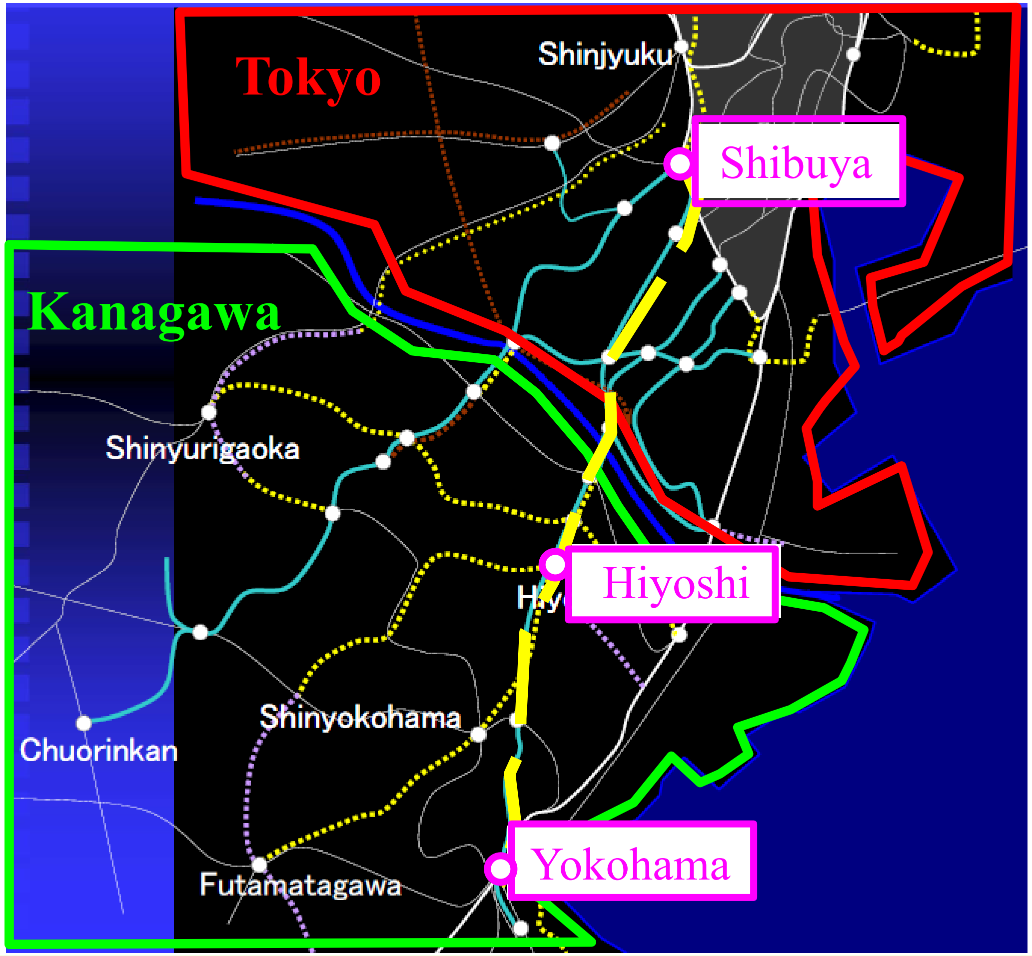
Contents

Typical Construction Case Histories of RRR GRS Structures

Project Overview

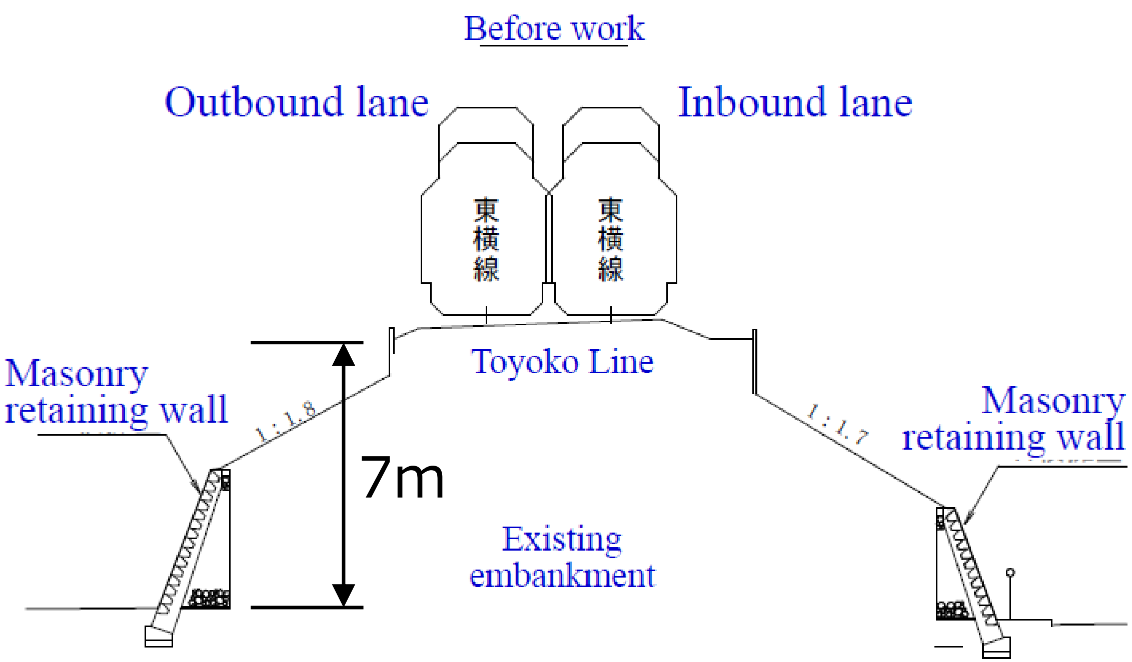
Building the future on new foundations
TOKYU CONSTRUCTION

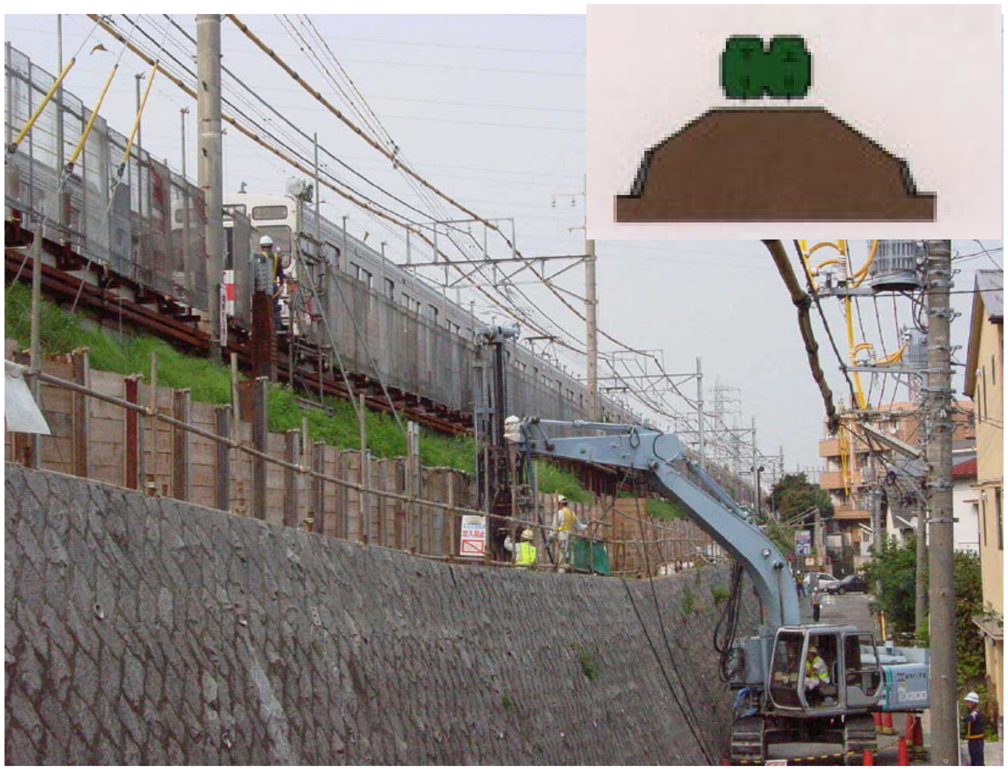
Transportation Network Improvement in the Metropolitan Area (2001)



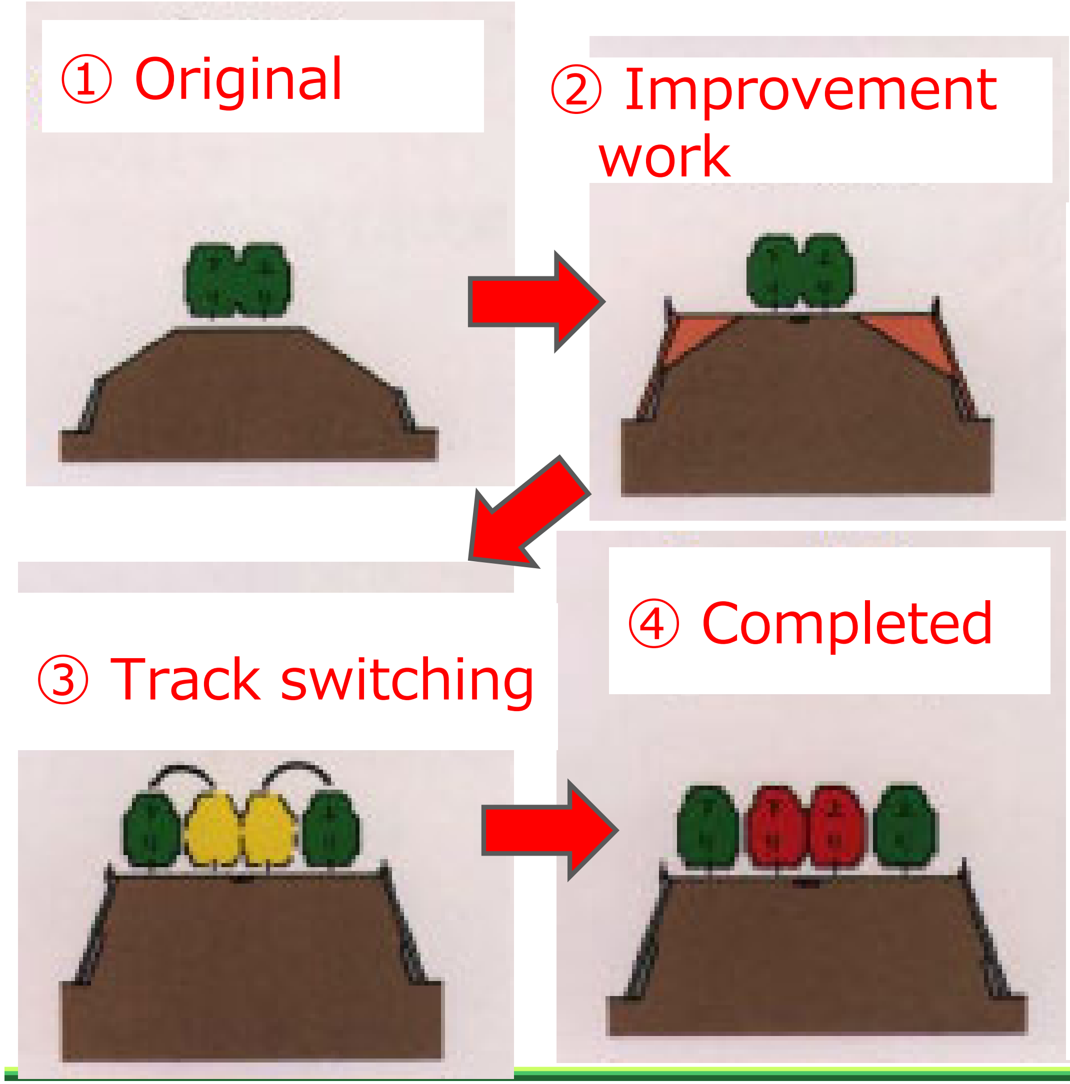
Track expansion outline and Section view

Before improvement work

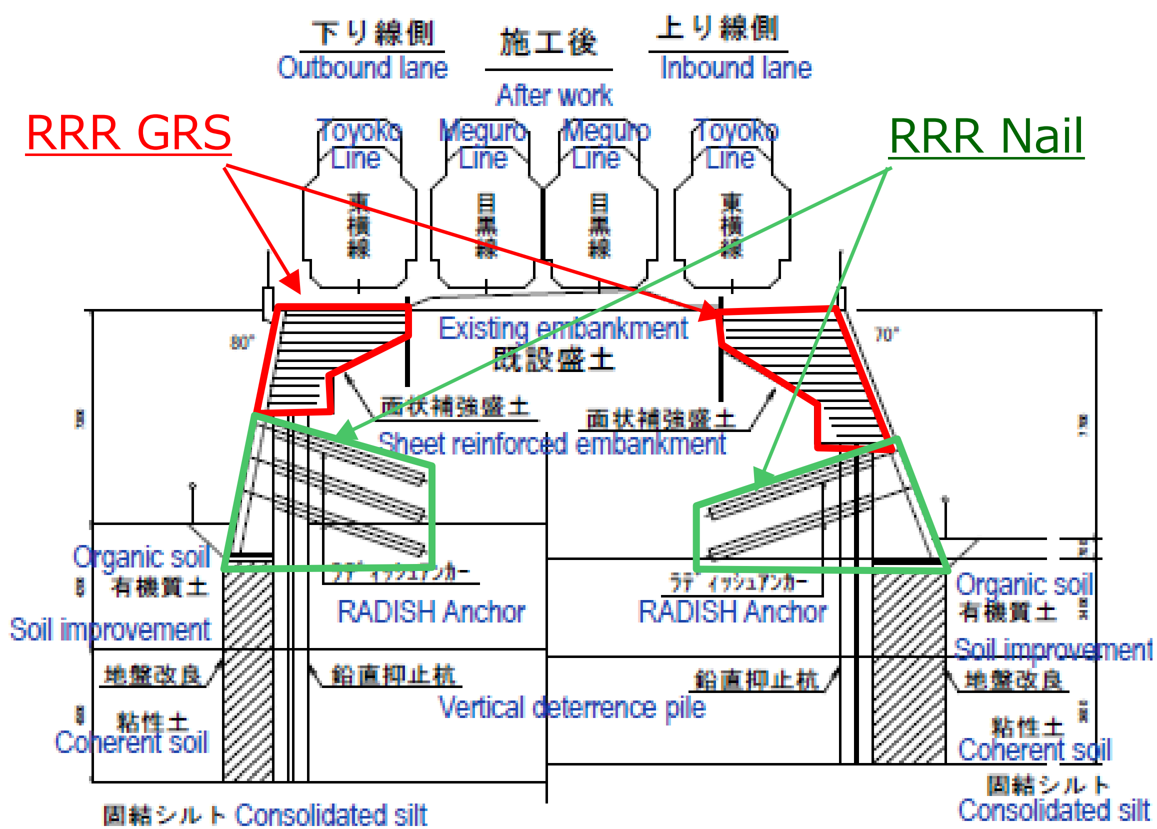




Track expansion outline and Section view



Structure of embankment



RRR GRS structures

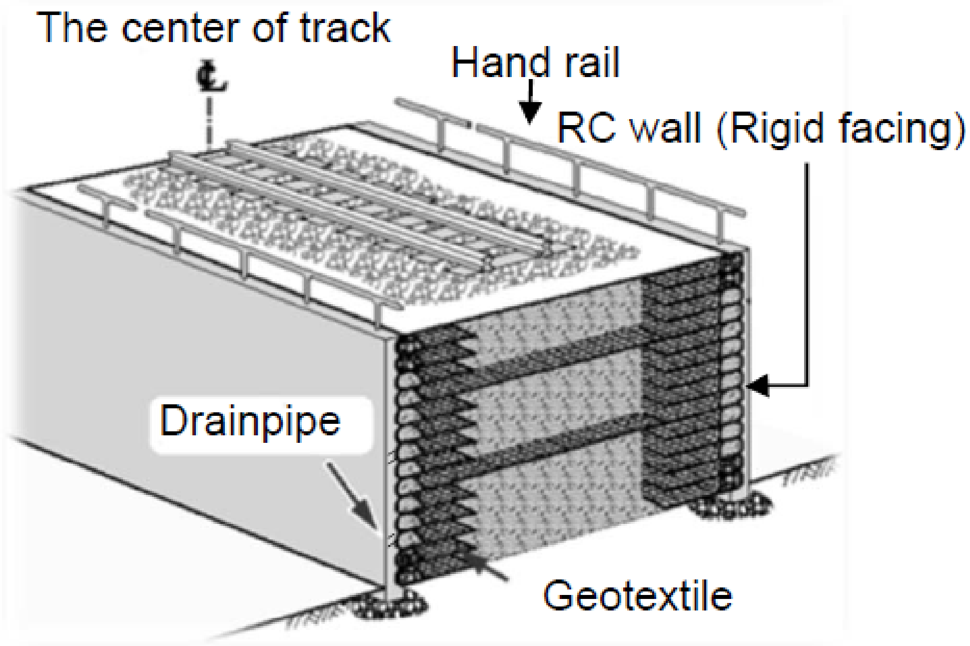
FHR facing is constructed connected to all the geogrid layers to effectively confine the backfill, creating a highly stable reinforced soil structure.

Advantages of RRR GRS structures

・Backfill remains very stable even under severe seismic loading

・No residual deformation during service

・No use of pile foundations, as RC FHR facing is constructed by casting-in-place concrete after the end of embankment settlement.



Overview of the RRR-B method

・High construction efficiency — suitable even at narrow sites.

RRR Nail structures

Use of large-diameter soil nails, instead of small-diameter steel metal nails, to reinforce existing embankment cut to a nearly vertical wall

RADISH anchors (φ40cm) adopted in this project

Large diameter provides high pull-out resistance even with short nails and efficient construction

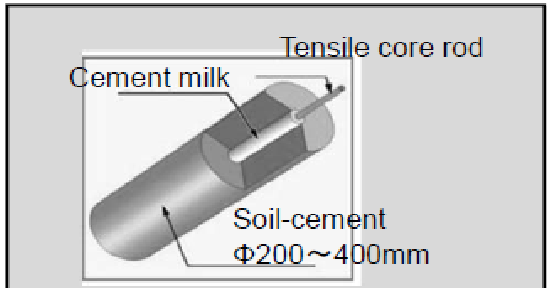
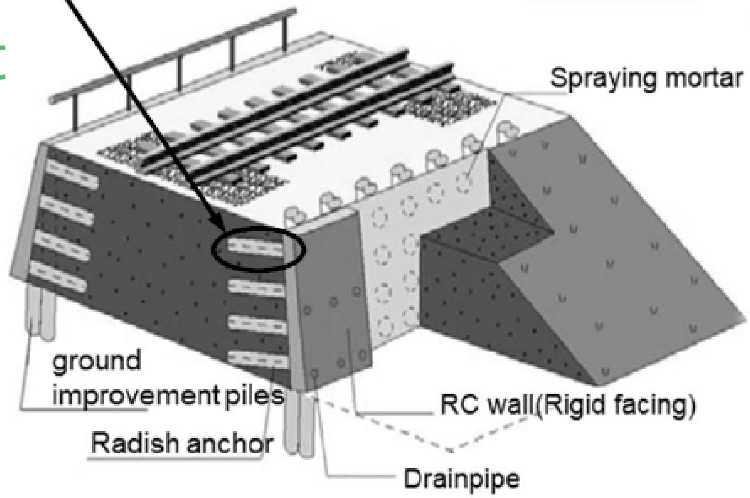


Diagram of the Radish anchor



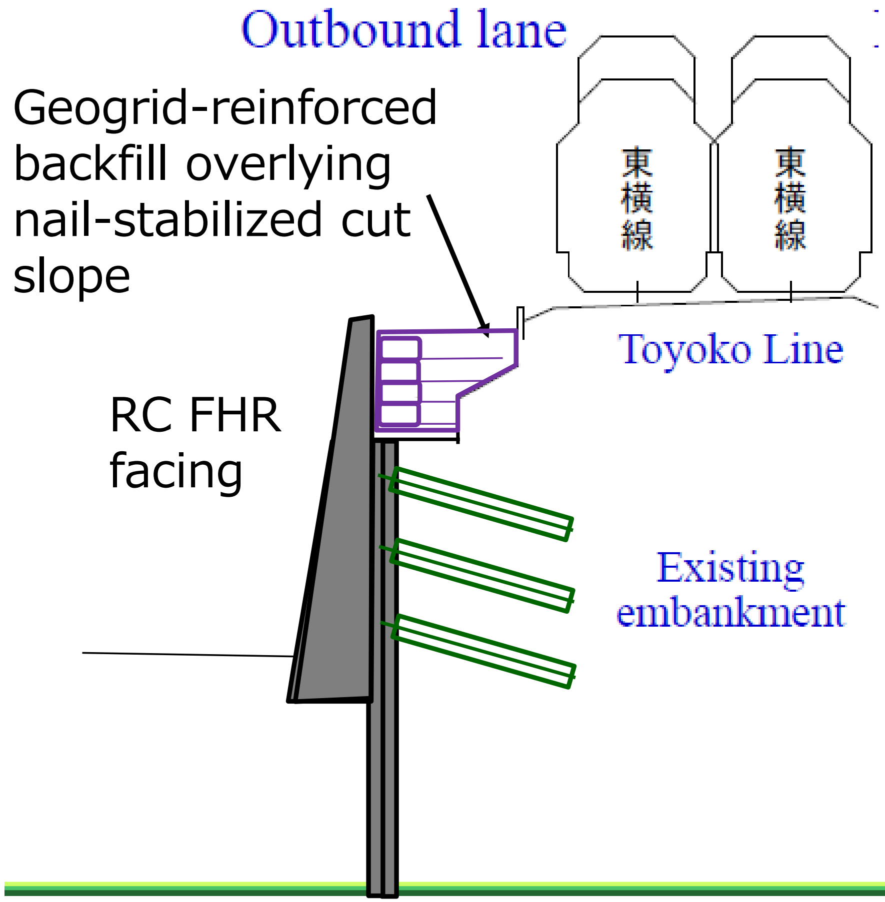
Overview of making a slope steeper

RRR Nail (RADISH anchor)

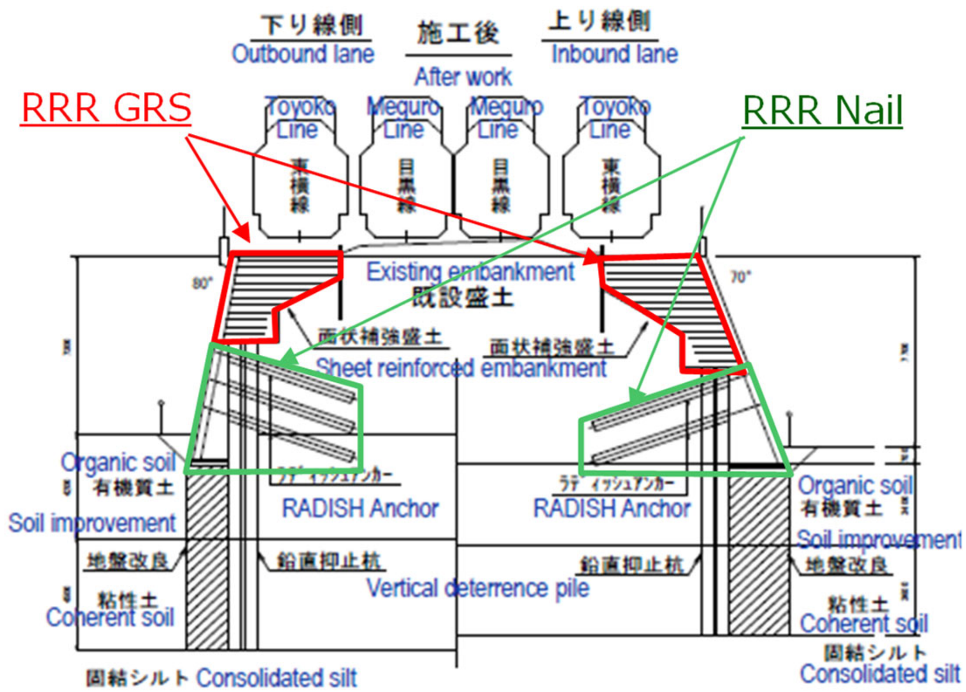

Excavated RADISH anchor

Construction process

Corss-section

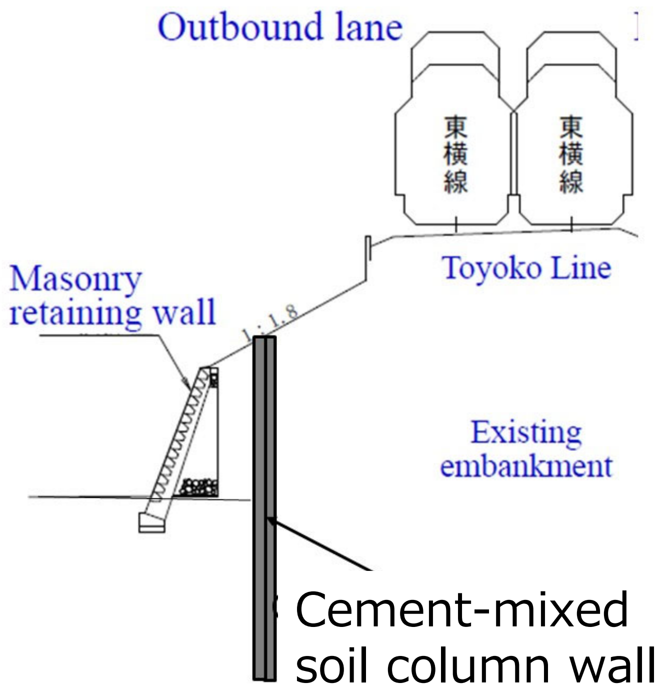


Structure of embankment



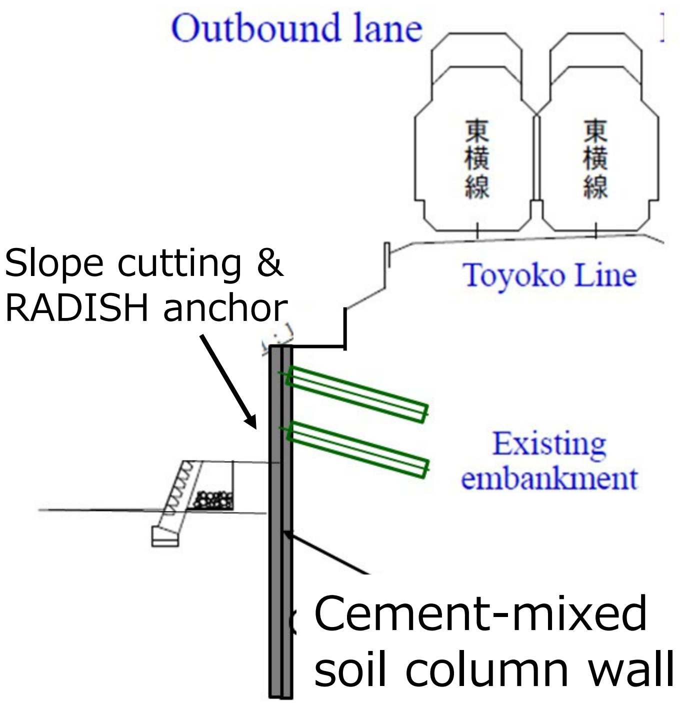
Construction process

1) Cement-mixed soil column as temporary retaining wall



Construction process

2)Installation of RADISH anchor



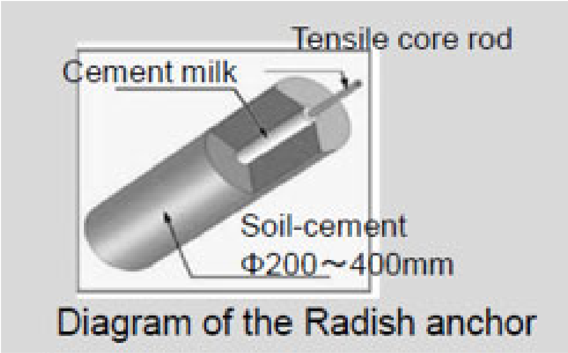
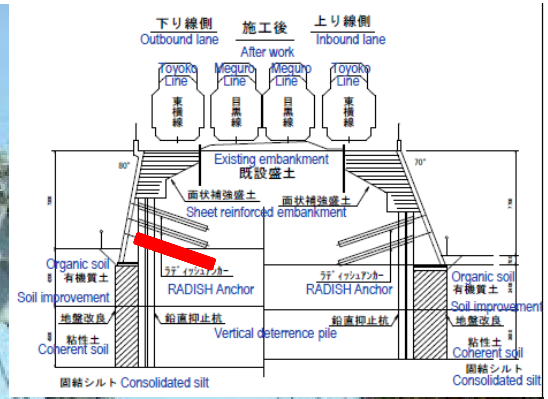
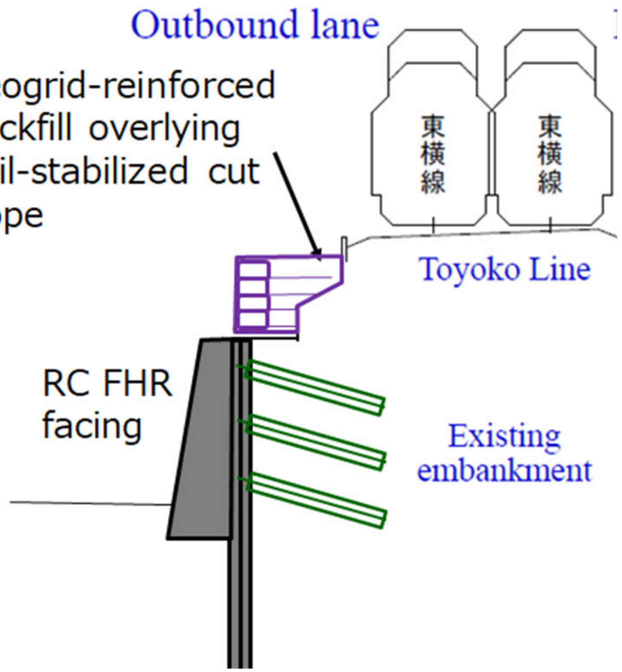


Diagram of the Radish anchor



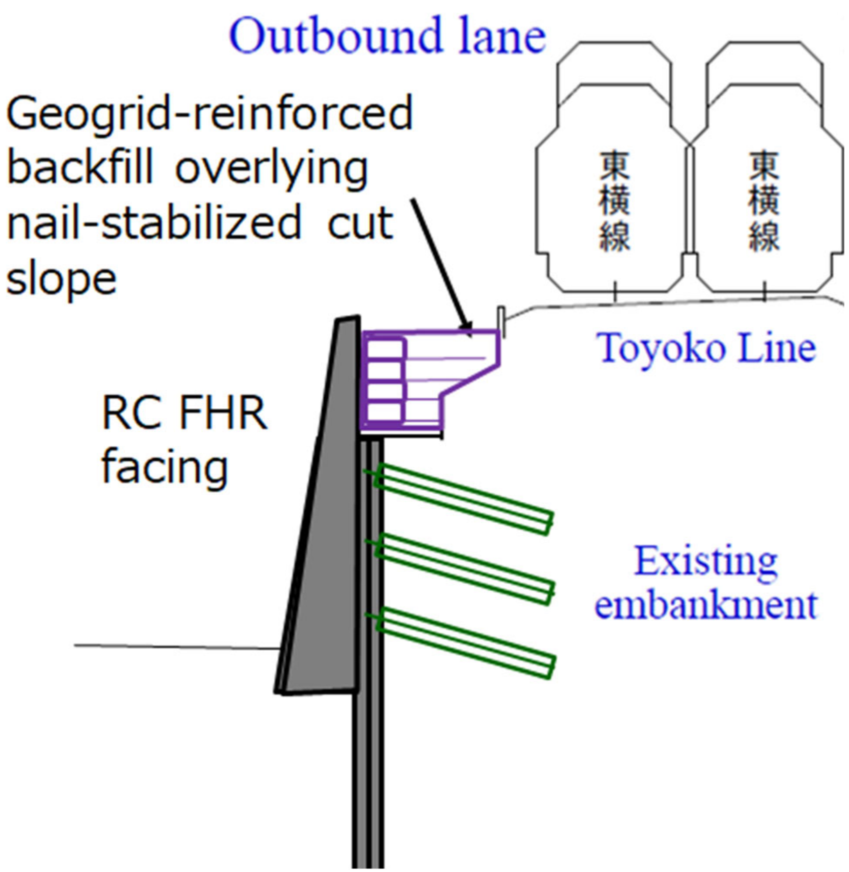
Construction process

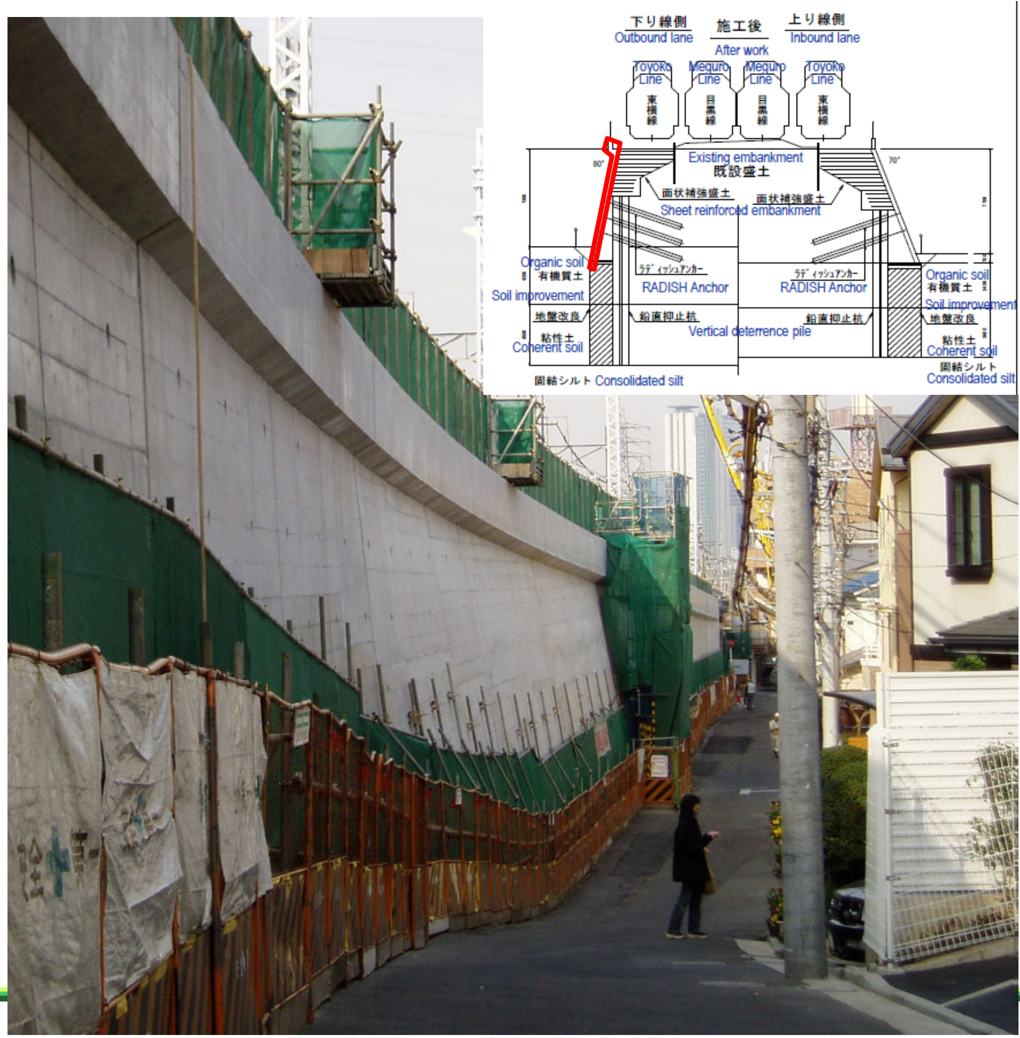
3)Arrangement of geogrid reinforcement



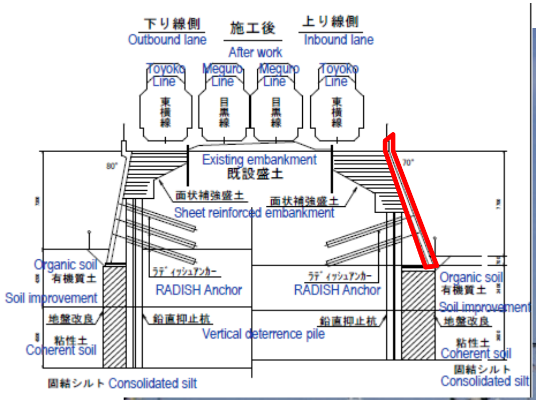
Construction process

4) Completion of RC wall (FHR facing)





4) Completion of RC wall (FHR facing)



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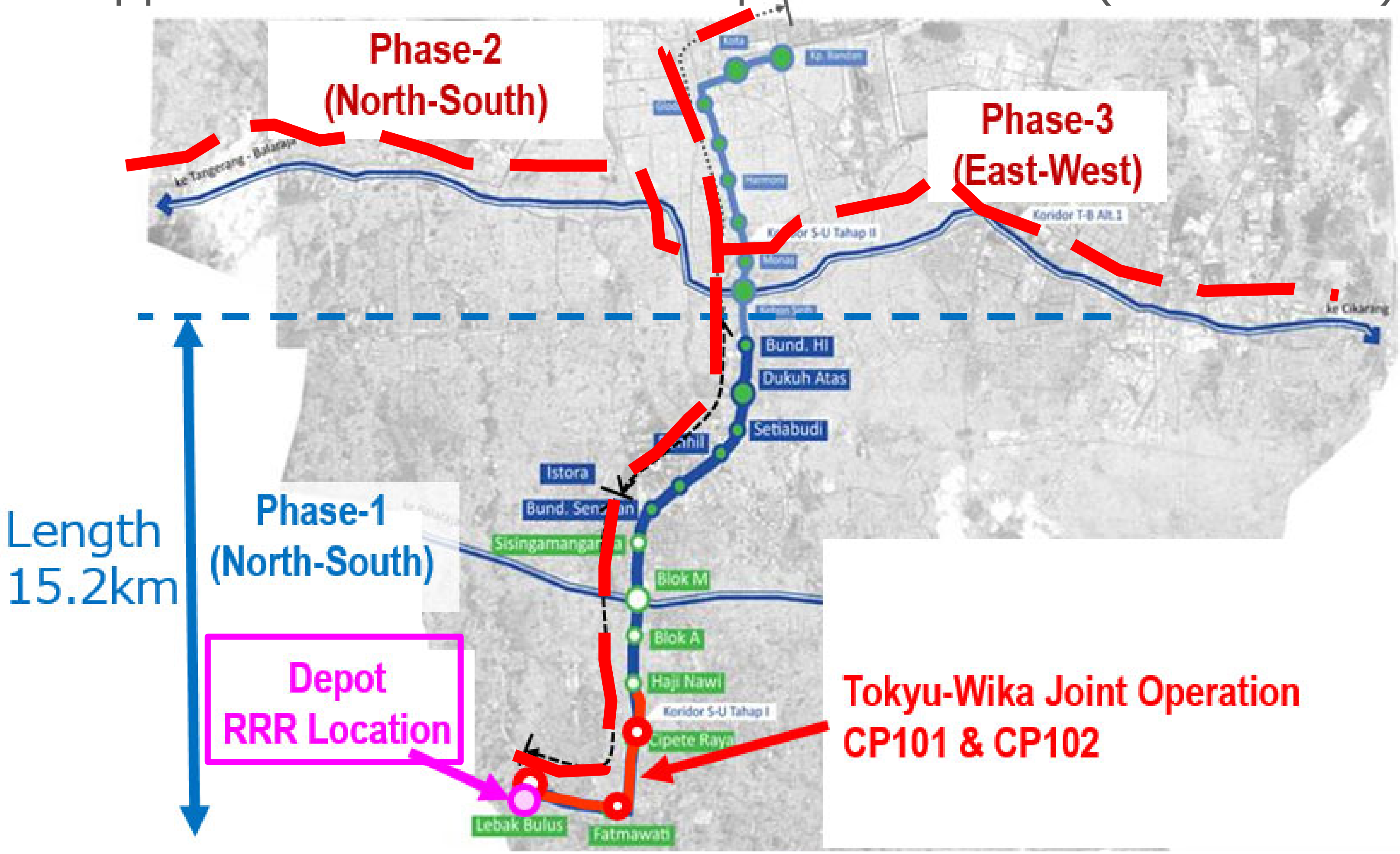
TOKYU CONSTRUCTION

Typical Construction Case Histories of RRR GRS Structures

1. Track Expansion for a Major Shibuya–Yokohama Commuter Line Using the RRR Method
2. First Implementation of the RRR Method in Indonesia: Perimeter Retaining Walls for the Jakarta MRT Depot
3. GRS Integral Bridges for the Sanriku Railway Reconstruction Project

Project Overview

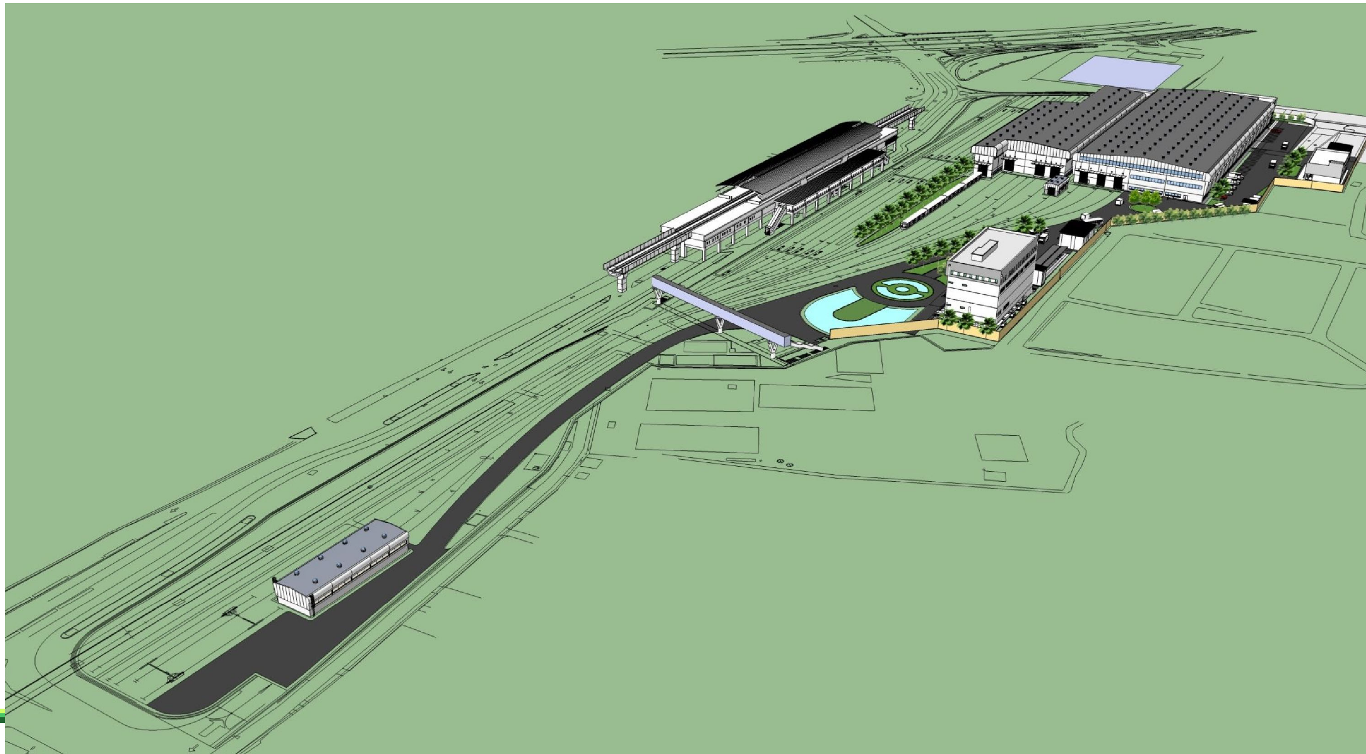
Connection of Jakarta north–south and east–west by MRT
RRR method applied at southernmost depot of Phase 1 (2013-2019)



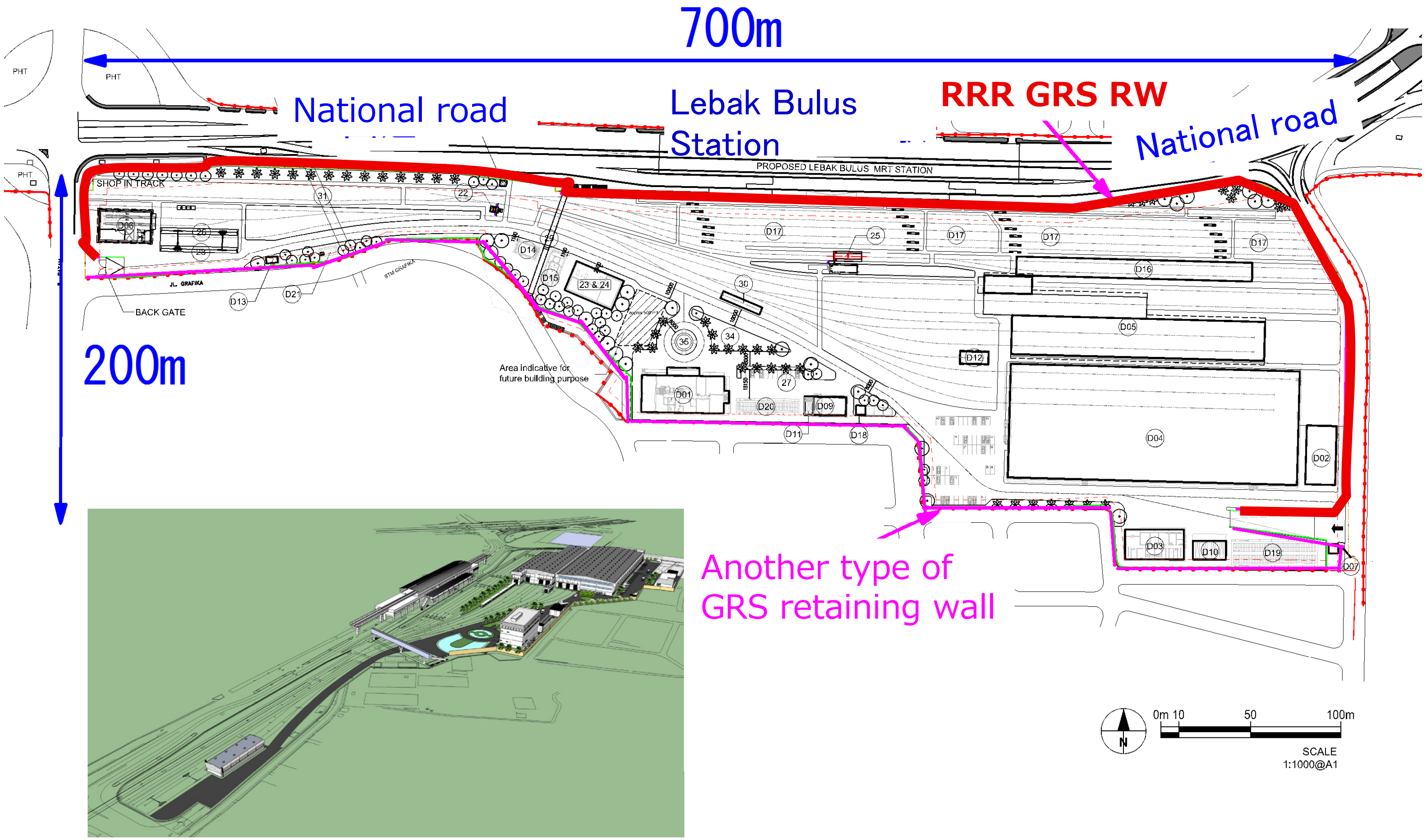
Project Outline

Contents of CP101 : CP101 Depot, Viaduct, Station

Quantities of Depot : Area A=83,000m^2
Embankment V=300,000m^3



Project Outline



Adoption of RRR GRS structure

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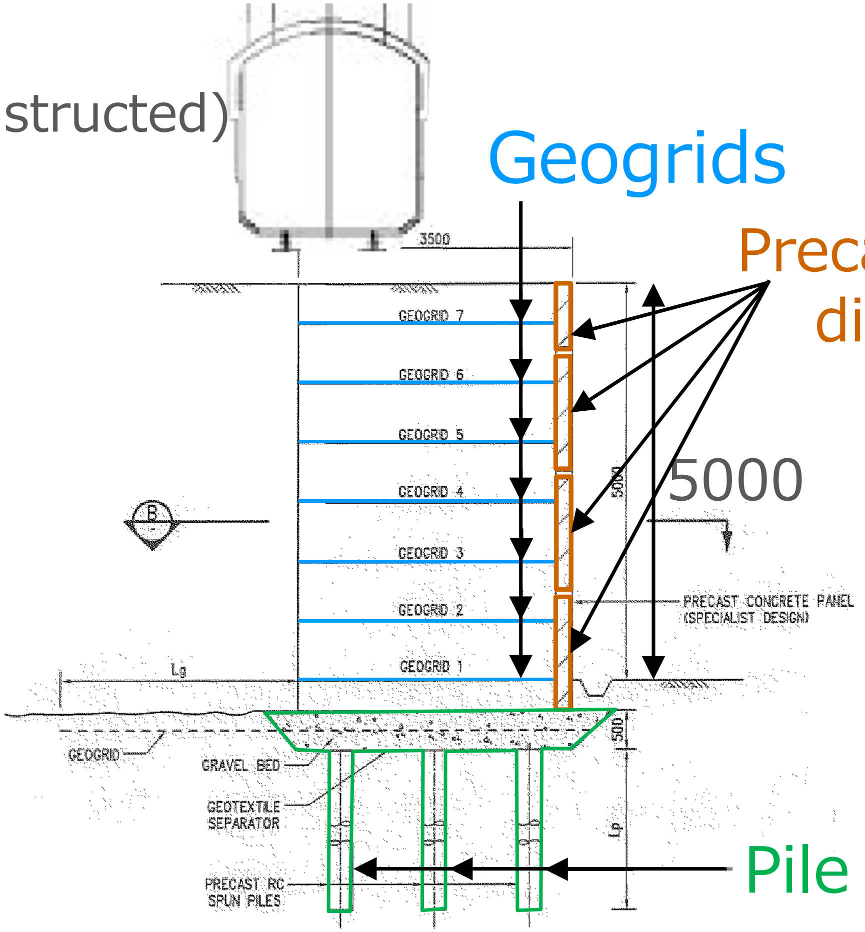
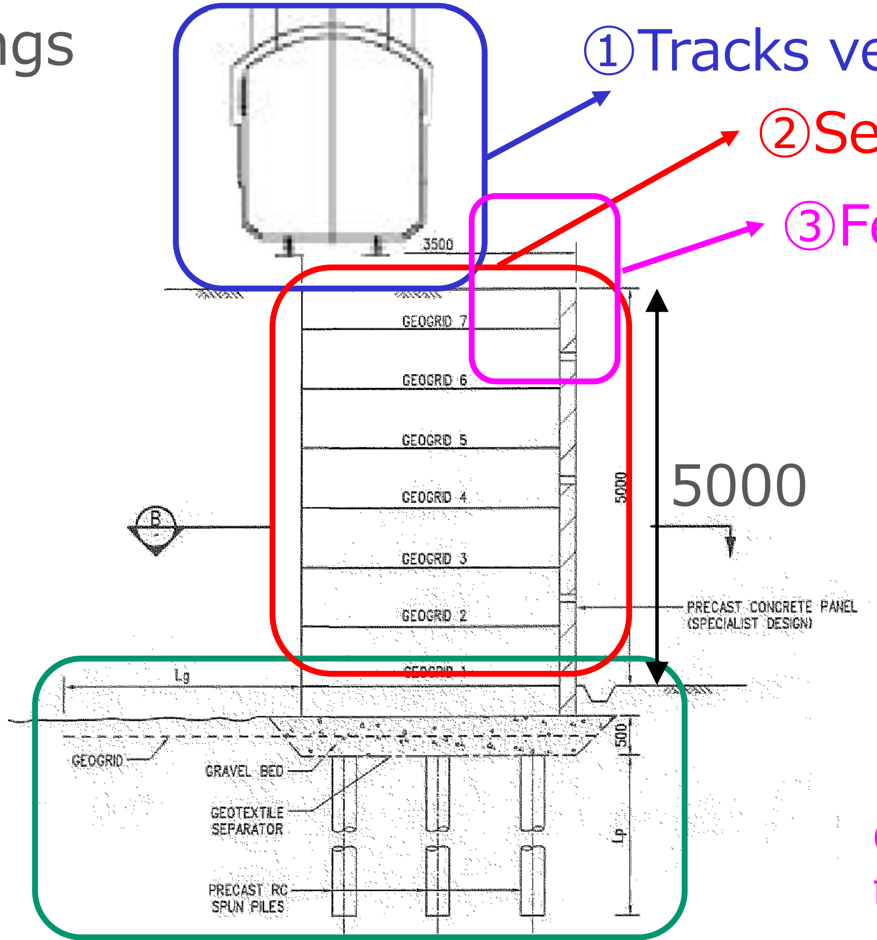
Tender drawings
(eventually not constructed)



Adoption of RRR GRS structure

Tender drawings

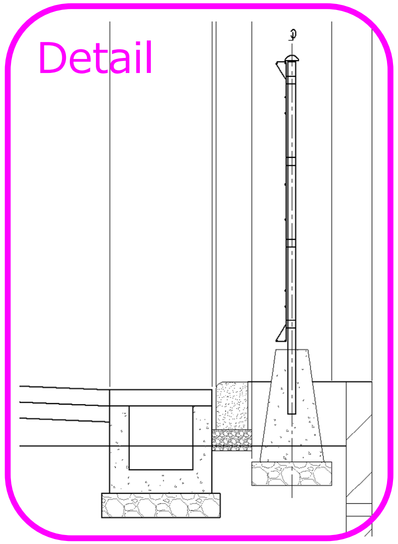


①Tracks very close to the wall face

②Seismic design required

③Fence installation required

Detail



Geogrid and
fence foundation interfere

④Omission of piles required
Soft ground (N < 6) → stability without piles

Adoption of RRR GRS structure

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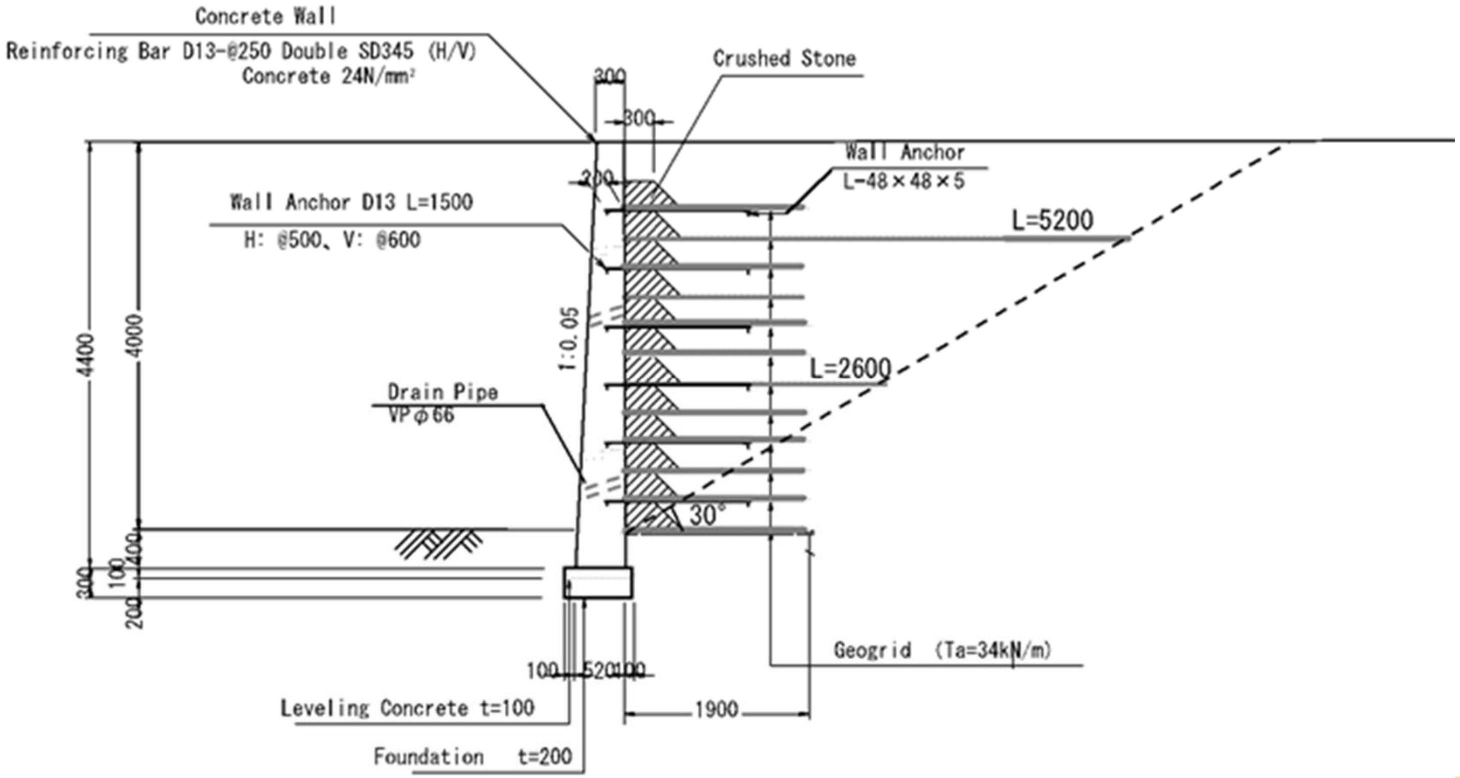
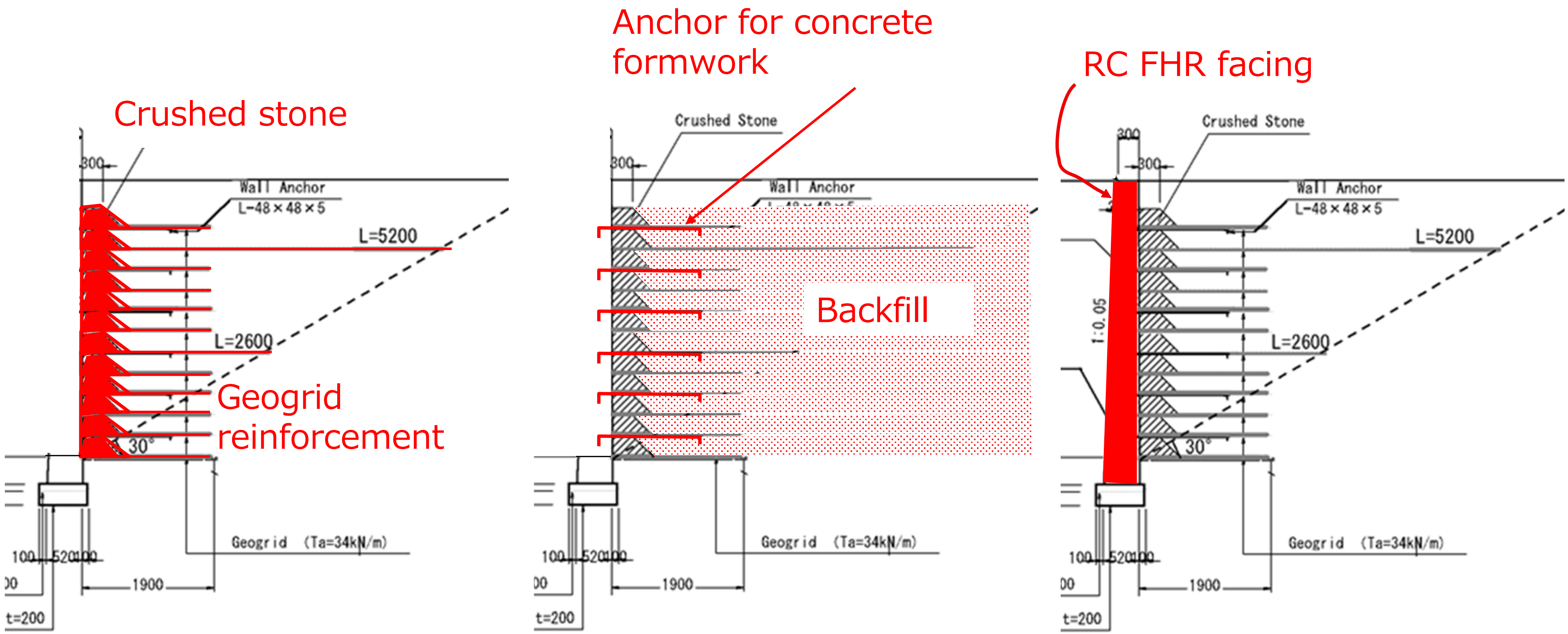
Widely applied to railway embankments in Japan
Can accommodate fence foundations on wall top
Allows omission of pile foundations → RRR GRS adopted for this project



Construction process



Problem Solving by Adopting RRR GRS

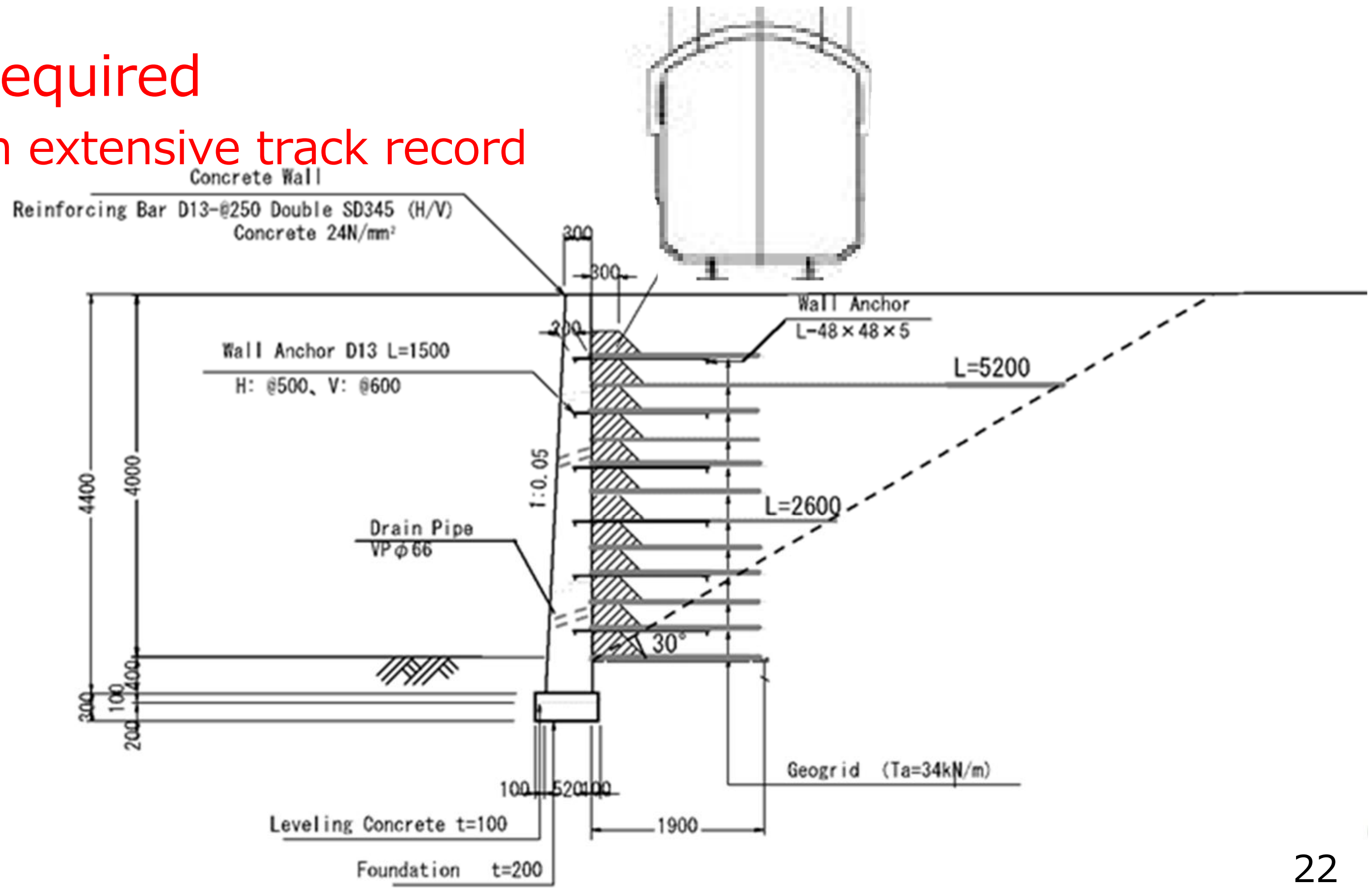
Challenge 1: Tracks very close to the wall face

-Proven performance in Japanese railway embankments

-Stable reinforced-soil structure suitable for narrow spaces

Challenge 2: Seismic design required

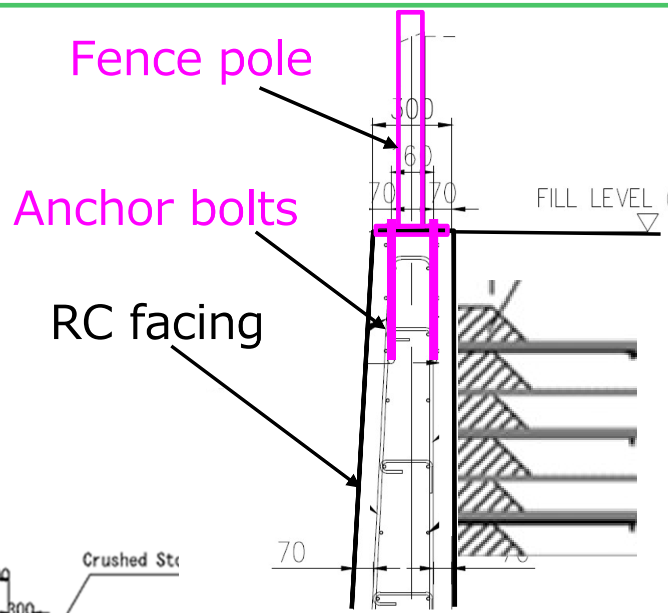
-Excellent seismic performance with extensive track record



Problem Solving by Adopting RRR GRS

Challenge 3: Fence installation required

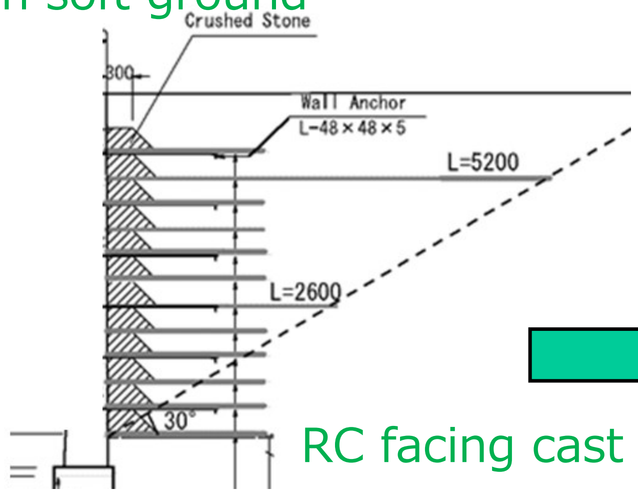
-RC FHR Facing allows direct connection with fence and pole foundations



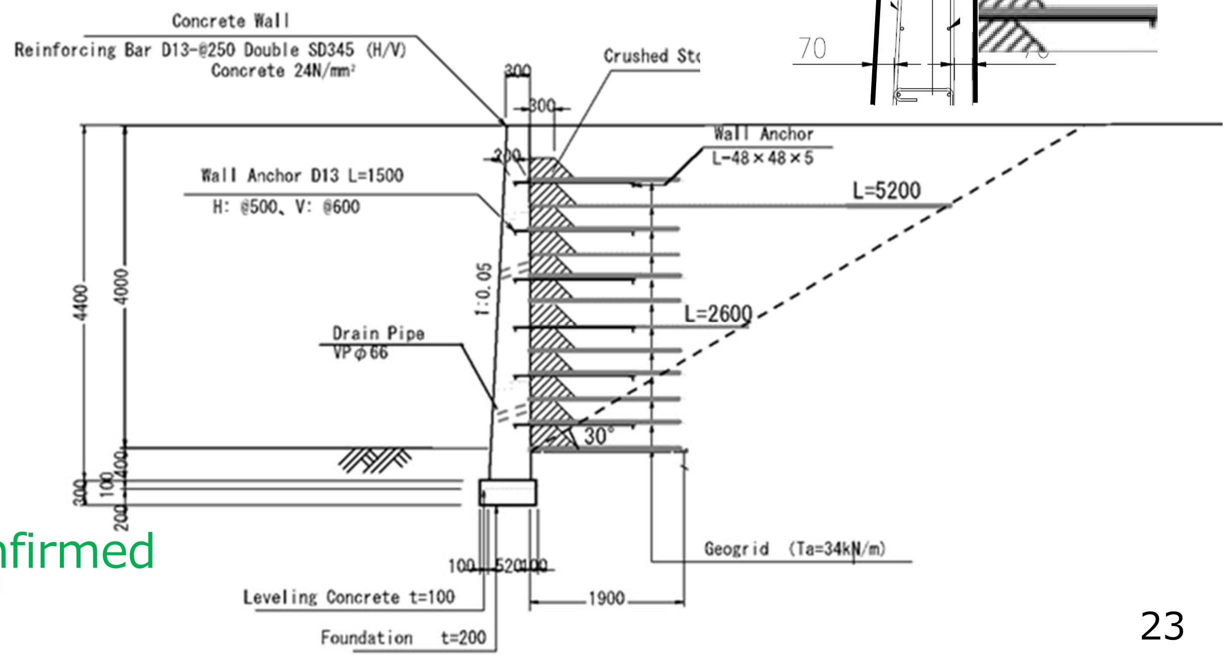
Challenge 4: Omission of piles required

-Reinforced-soil structure built first to stabilize the ground

-RC FHR Facing constructed afterward, enabling safe construction even on soft ground

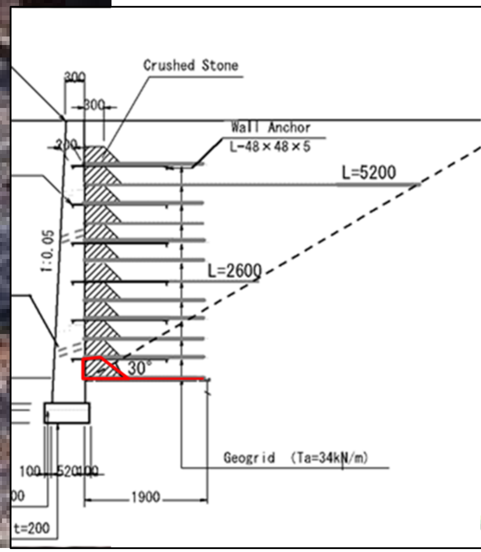


RC facing cast in place
after soil stability is confirmed



Construction process

1. Placement of Geogrid

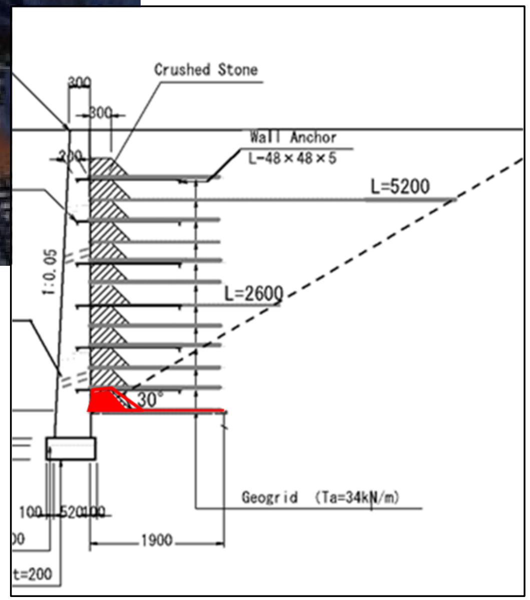


Construction process

2. Temporary Facing Unit of Welded Wire Mesh

Compacting crushed stone

Folding geogrid

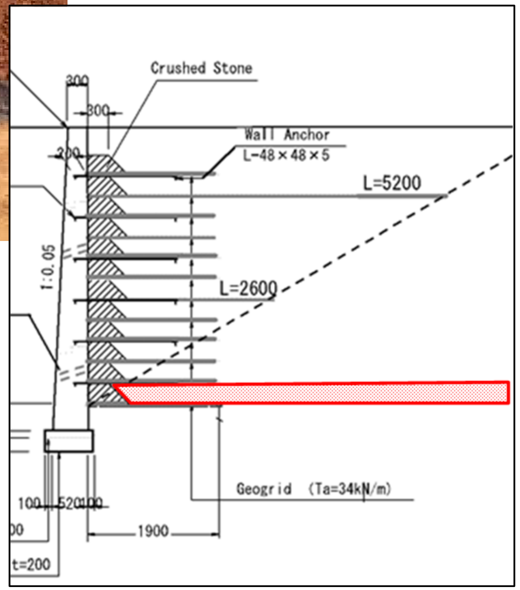


Construction process

3. Compaction of Backfill Material

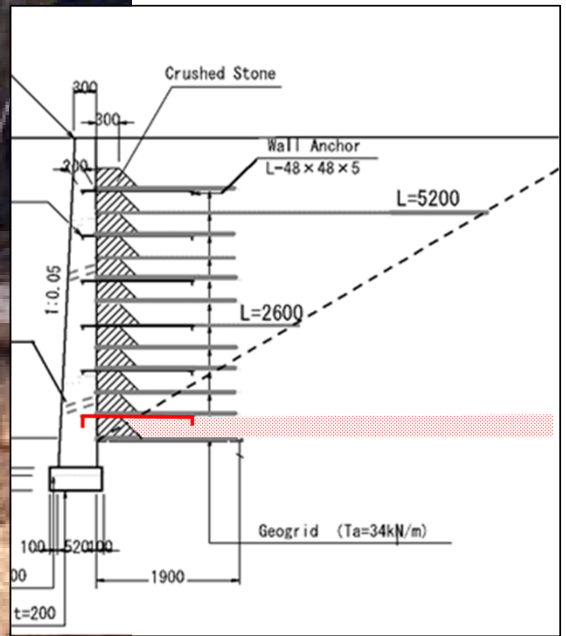
Spreading of sandy material

Compaction with Vibratory Roller



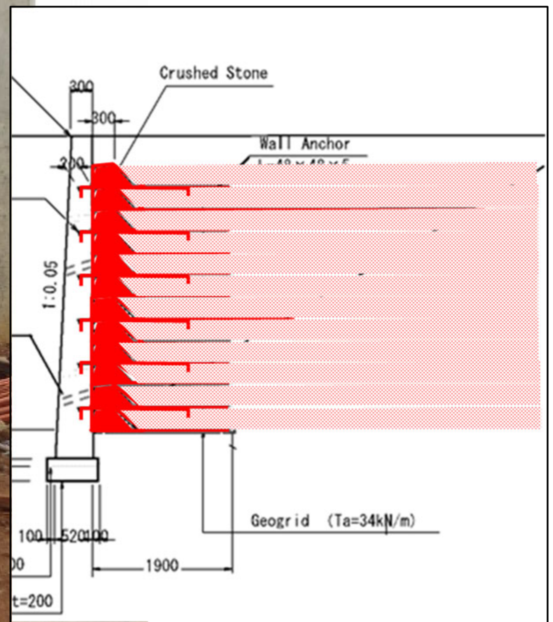
Construction process

4. Installation of anchor for the concrete formworks



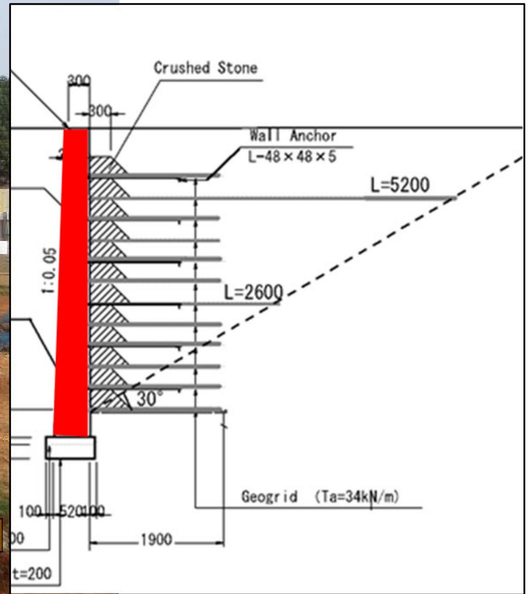
Construction process

5.Completion of Reinforced soil (before the construction of FHR facing)



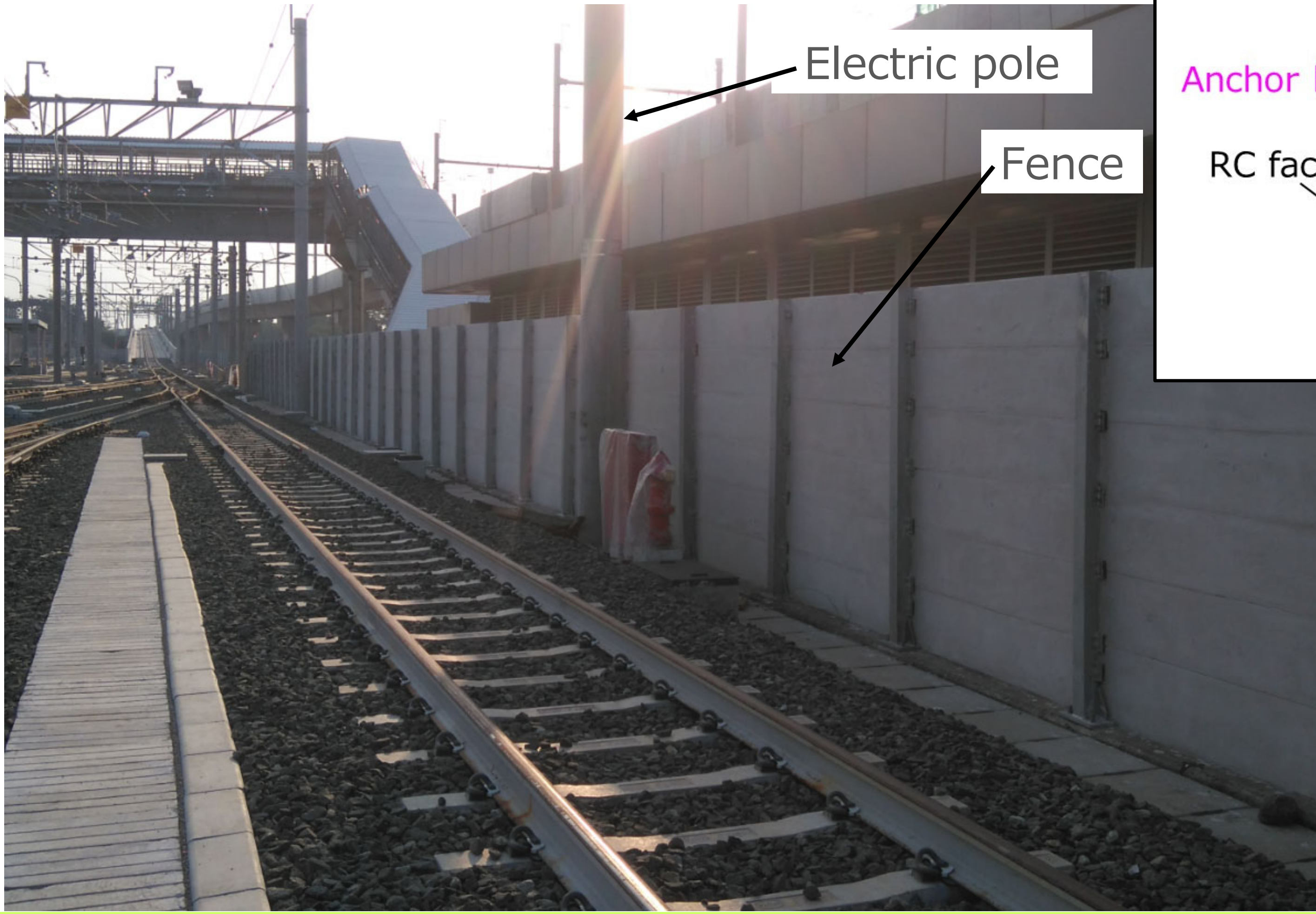
Construction process

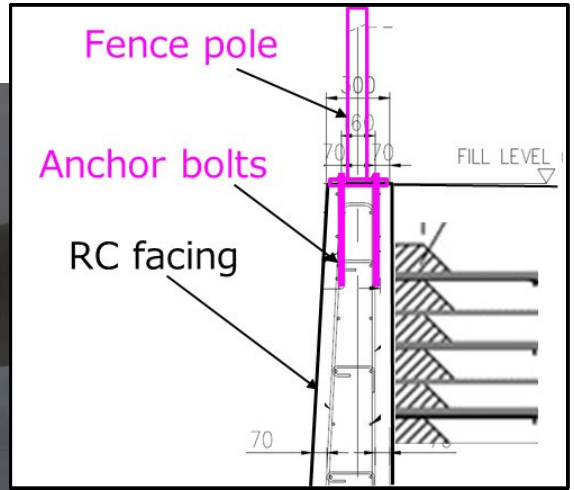
6.Completion of RC wall (FHR facing)



Integration with Fence Foundation

Top of RRR backfill with Railway track





Overall of the view depot

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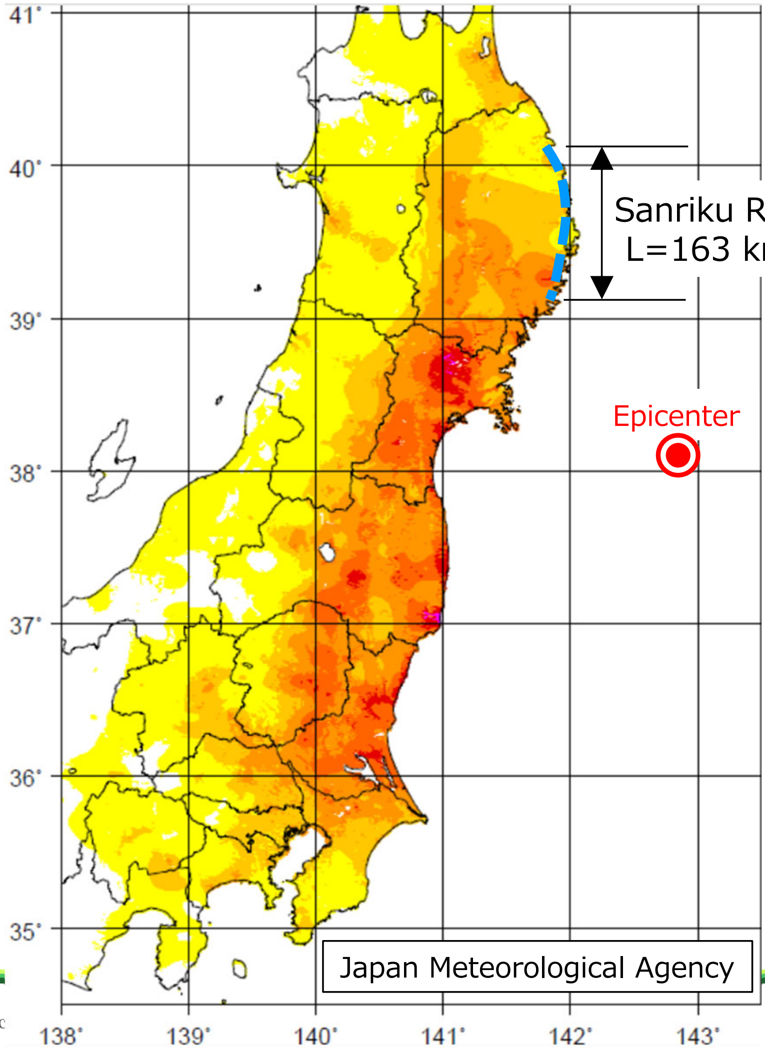
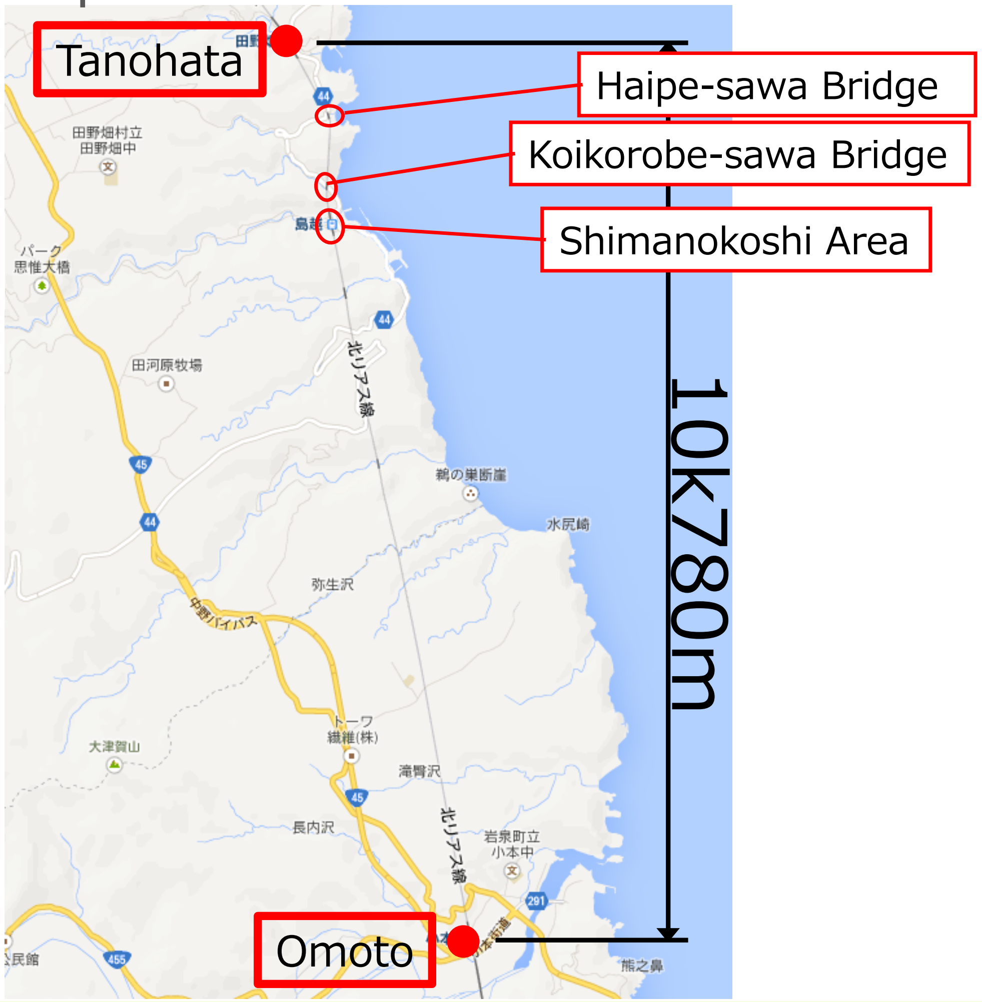
Background

The 2011 off the Pacific coast of Tohoku Earthquake





Background

Building the future on new foundations
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The 2011 off the Pacific coast of Tohoku Earthquake

Adoption of RRR GRS structure

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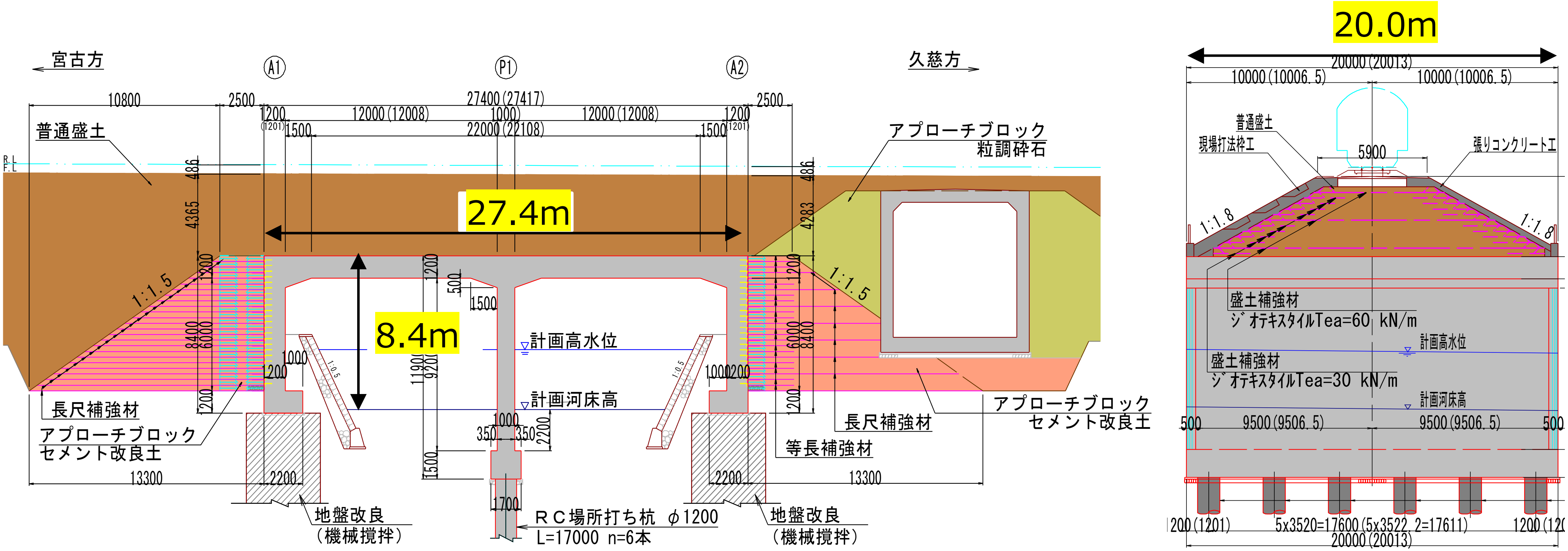
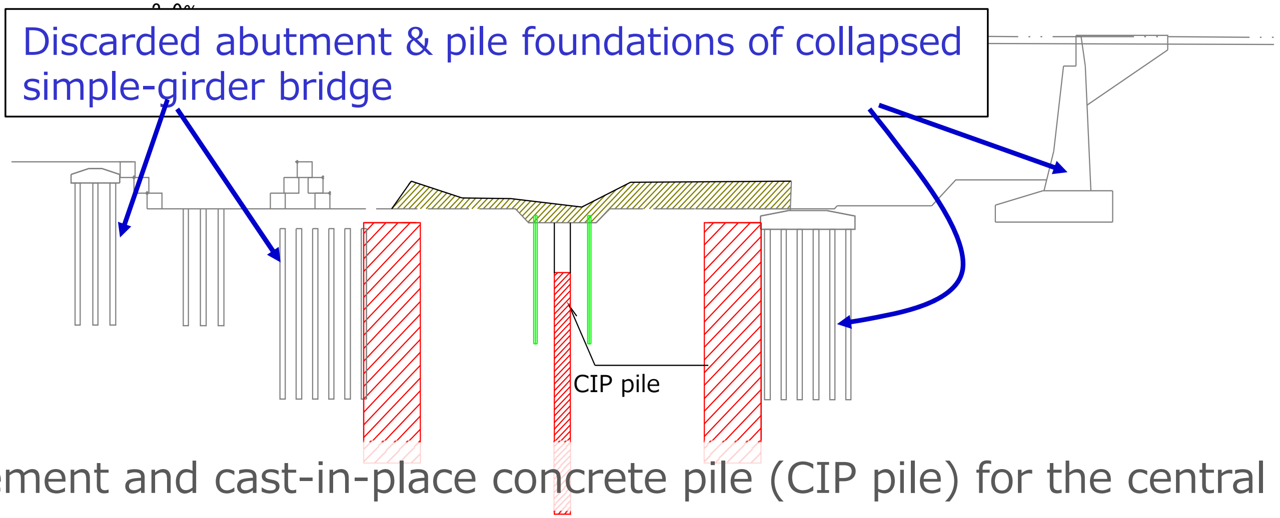
Structure & Features of the GRS Integrated Bridge(Shimanokoshi area)

GRS integrated bridge with a two-span continuous girder and a central pier located in a river: bridge length: 27.4 m / Height: 8.4 m / Width: 20.0 m
Geogrid-reinforced embankment constructed also over the bridge



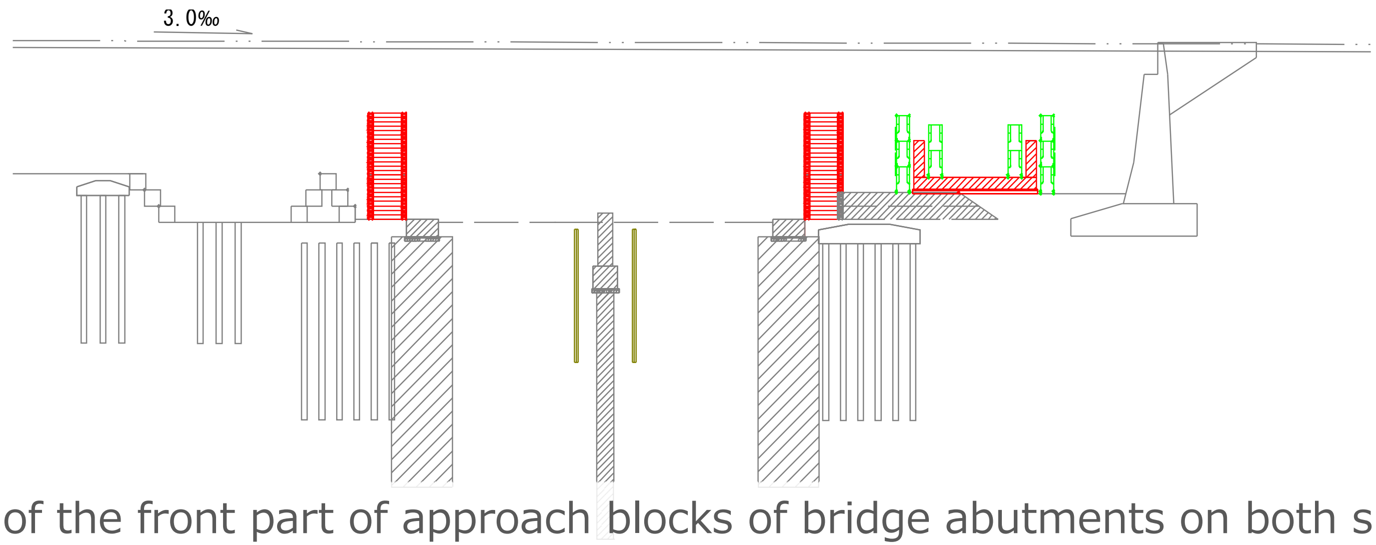
Construction process

①



Ground improvement and cast-in-place concrete pile (CIP pile) for the central pier

②



Construction of the front part of approach blocks of bridge abutments on both sides

Construction process

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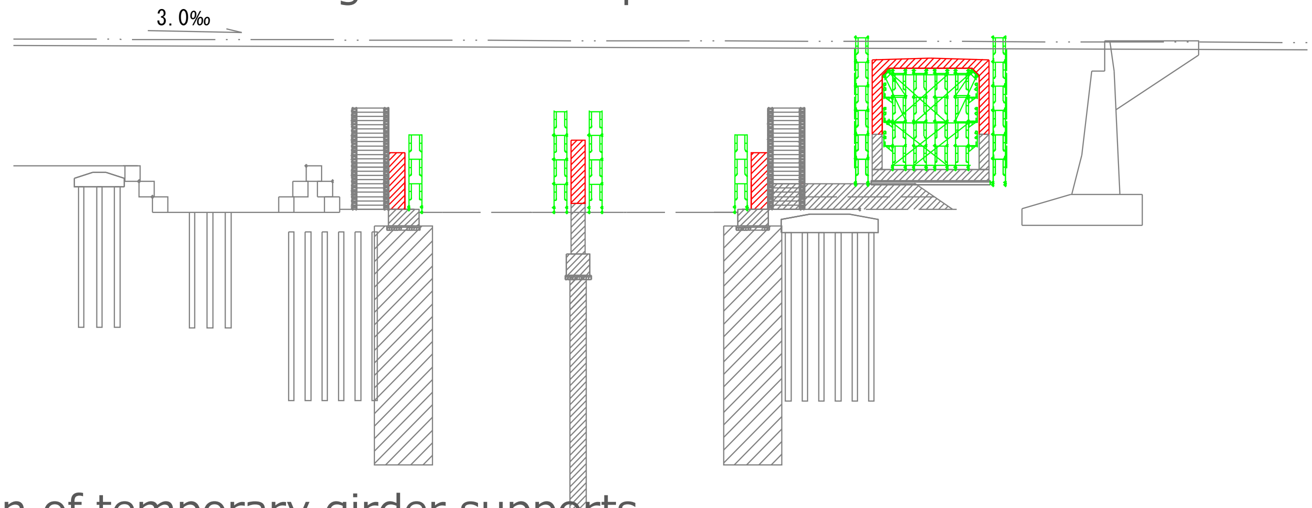
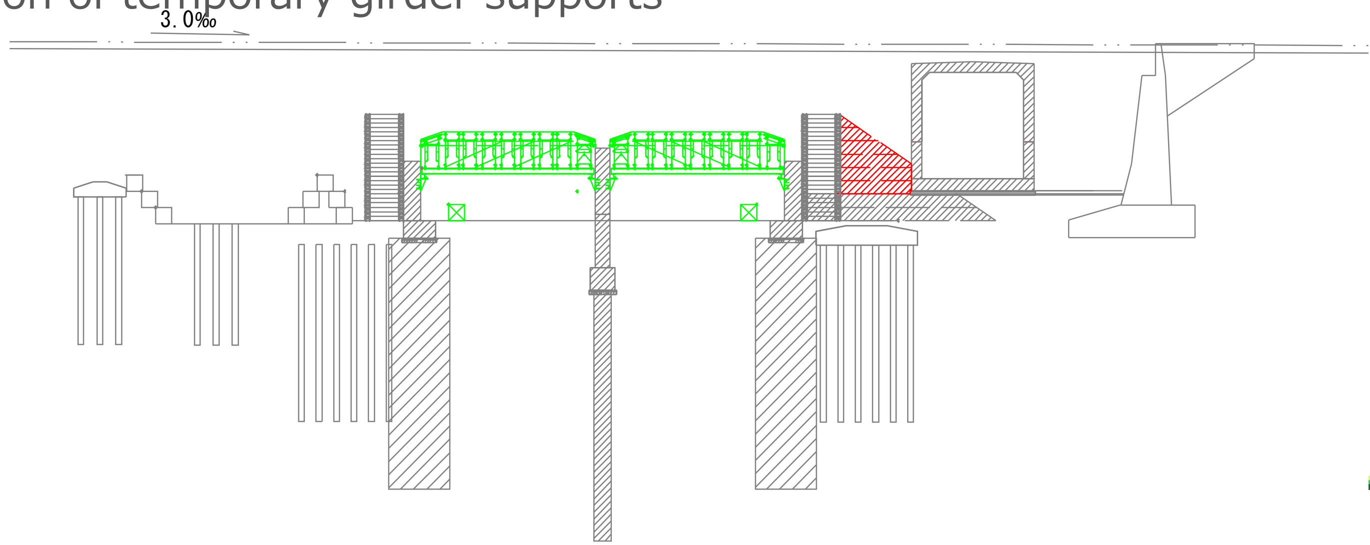
③ Construction of FHR facing and central pier

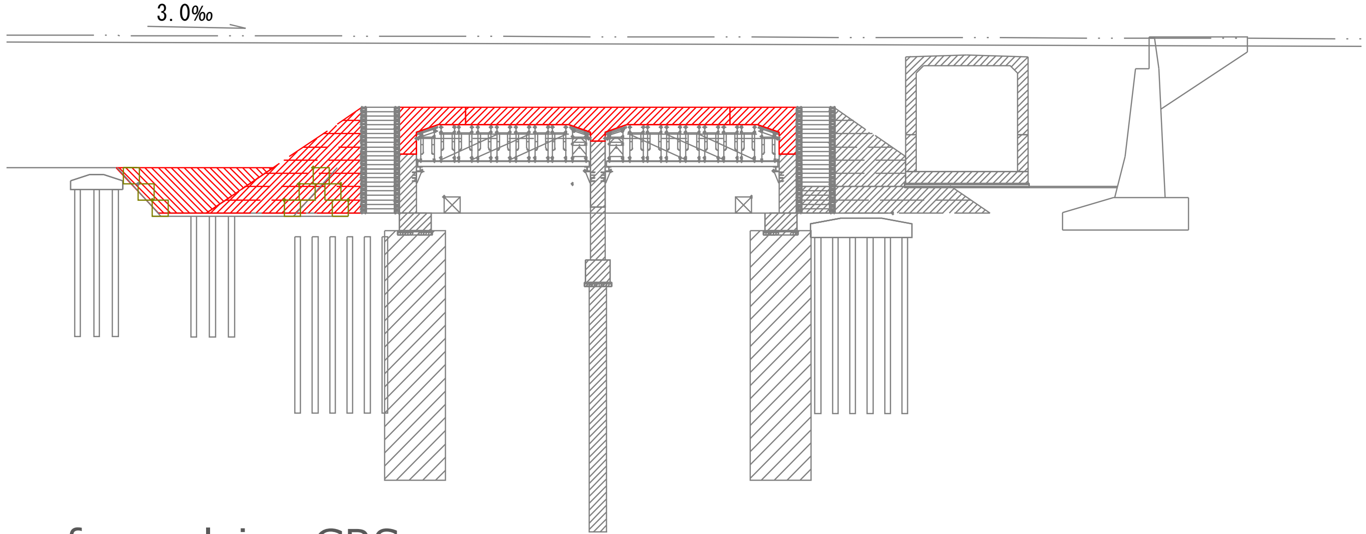


④ Installation of temporary girder supports

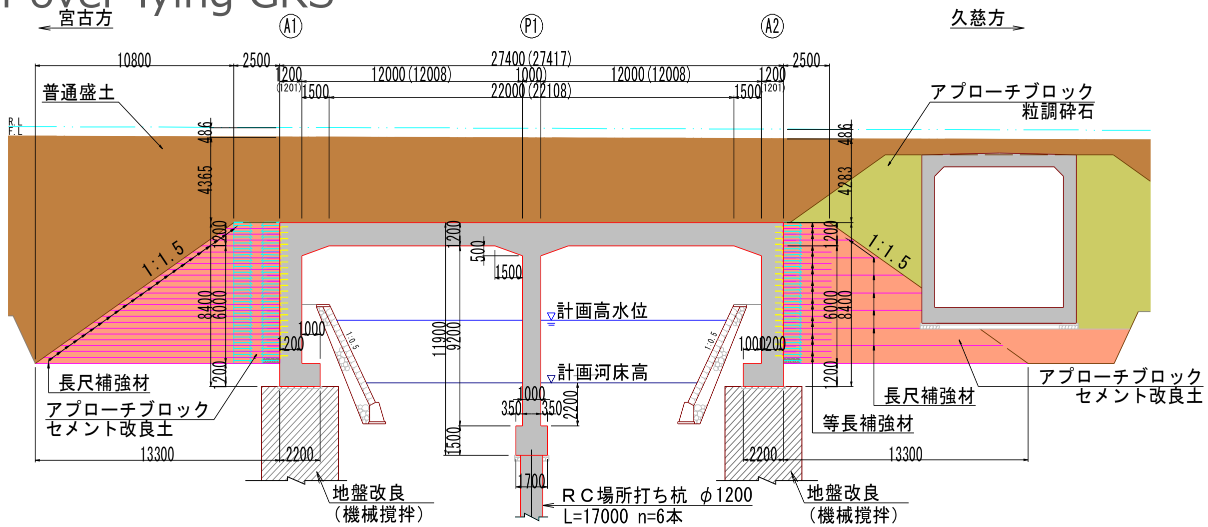


Construction process

⑤ Construction of approach block and continuous girder



⑥ Construction of over-lying GRS



Construction procedures

Before re-construction

Ground improvement by Sand Compaction Piles

Construction process

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Construction process

Construction process

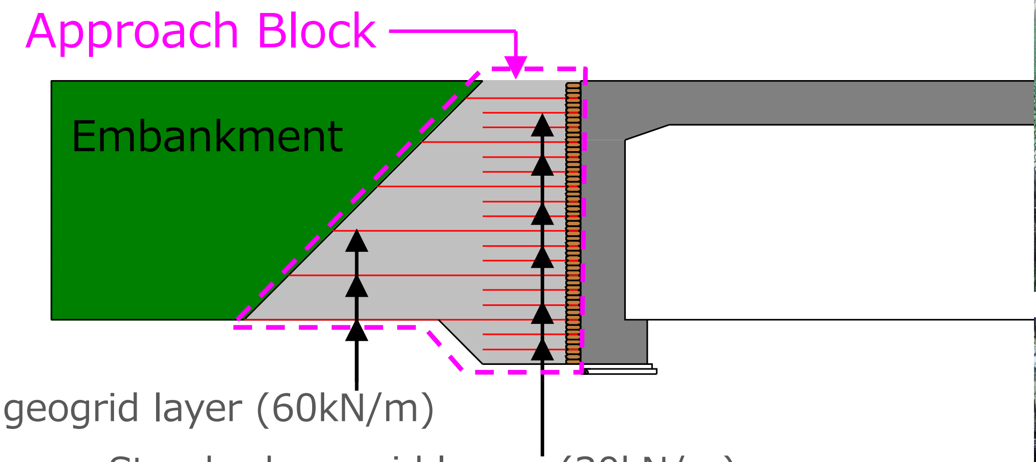
Construction process


Construction of GRS structures and bridge structure


Removal of temporary girder supports

Construction of Approach Block for GRS abutment

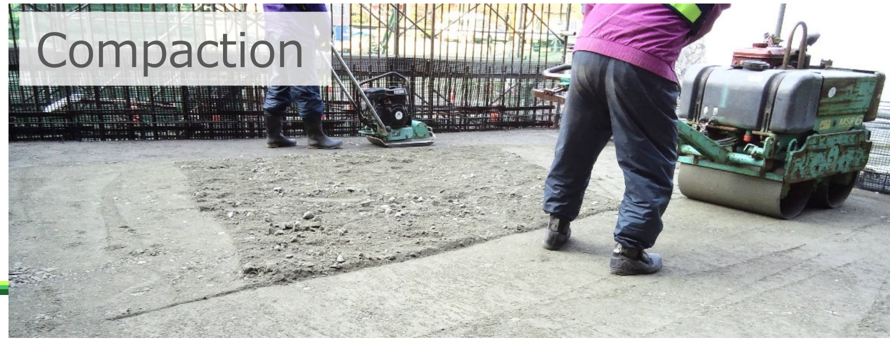
General view




Placement of geogrid


Spreading of fill material


Cement-Mixing of fill material in a Soil Tank


Compaction

Full-Service Restoration

Conclusions

Building the future on new foundations
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Case Histories of the Construction of RRR GRS Structures

・Presented three RRR case histories with different project goals

・RRR technology effectively resolved site-specific technical challenges

・Demonstrated a high flexibility in different projects: embankment widening, depot retaining structures, and GRS integral bridge

・RRR continues to contribute to safer and more resilient railway infrastructure

Thank you for your kind attention